SLOPE HAZARD ASSESSMENT SYSTEM FOR WASHINGTON'S FORESTED LAND

PHASE I

By

Golder Associates

TIMBER FISH & WILDLIFE

DRAFT

JUNE 28, 1991

<u>ENGINEERING ROCK UNIT</u>

		Character of Discontinuity											Surface Properties			Impact Material Grade
Rock Unit	Set Number	Failure Mechanism			Discontinuity Dip (degrees)				Persistence							
		Planar	Wedge	Topple	0-25	25-50	50-75	>75	<10°	10-30°	>30°	Smooth/Sheared	Rounds	V. Rough/Irregular	

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ROCK UNIT:
Assign an arbitrary letter for each lithologic type.

SET NUMBER:
Assign a sequential number for each fracture set in the lithologic unit.

CHARACTER OF DISCONTINUITY
FAILURE MECHANISM:
Mark the box which best describes the mechanism of failure.

DISCONTINUITY DIP (degrees):
Mark the box which best brackets the majority of the discontinuity dip direction into the cut of feature.

PERSISTENCE
Mark the box which best brackets the range for most of the spacing of the set.

SURFACE PROPERTIES
Mark the box which best describes the dominant surface texture of the discontinuities of the set.

INTACT MATERIAL GRADE
Indicate the grade, as listed below, which corresponds to the rock unit and set.

GRADE	ROCK DESCRIPTION	FIELD IDENTIFICATION
R0	Extremely Weak	Indented by thumbnail.
R1	Very Weak	Crumbles under firm blows with point of geologist hammer, can be peeled by a pocket knife.
R2	Weak	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geologist hammer.
R3	Medium Strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single blow of geologist hammer.
R4	Strong	Specimen requires more than one blow of geologist hammer to fracture.
R5	Very Strong	Specimen requires many blows of geologist hammer to fracture.
R6	Extremely Strong	Specimen can only be chipped with geologist hammer.

Description	Criteria for Describing Toughness
LOW	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
MEDIUM	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
HIGH	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

ESTIMATE OF PLASTICITY ON SOIL PASSING THE #200 SIEVE

PLASTICITY

1) Describe the plasticity of the material in accordance with the criteria shown in Table 4.

Description	Criteria for Describing Plasticity
NONPLASTIC	A 1/8 inch diameter thread cannot be rolled at any water content.
LOW	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
MEDIUM	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
HIGH	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

USCS CLASSIFICATION

The soil material should be classified according to the system presented in Appendix A. In addition, the inorganic fine grained soil can be identified using the result of the descriptions applied from Dry Strength, Dilatancy and Toughness, see Table 6 below:

SOIL SYMBOL	DRY STRENGTH	DILATANCY	TOUGHNESS
ML	NONE TO LOW	SLOW TO RAPID	LOW OR THREAD CANNOT BE FORMED
CL	MEDIUM TO HIGH	NONE TO SLOW	MEDIUM
MH	LOW TO MEDIUM	NONE TO SLOW	LOW TO MEDIUM
CH	HIGH TO VERY HIGH	NONE	HIGH

Description	Criteria for Describing the Reaction of Pressure to the Dry Sample
NONE	Crumbles into powder with mere hand pressure.
LOW	Crumbles into powder with some finger pressure.
MEDIUM	Breaks into pieces or crumbles with considerable finger pressure.
HIGH	Cannot be broken with finger pressure. Breaks into pieces between thumb and a hard surface.
VERY HIGH	Cannot be broken between the thumb and a hard surface.

DILATENCY

1) Select material to mold into a 1/2 inch diameter ball, adding water if necessary until it is soft but not sticky

2) Smooth the ball in the palm of the hand with a small spatula.

3) Shake horizontally by striking the side of the hand vigorously against the other several times. Note th reaction of water appearing on the surface of the soil.

4) Squeeze the sample by closing the hand or pinching the soil between the fingers. Note the reaction i accordance with the criteria in Table 2. The reaction is the speed with which water appears while shakin and disappears while squeezing.

Description	Criteria for Describing Dilatancy
NONE	No visible change in the specimen.
SLOW	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
RAPID	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

TOUGHNESS

1) Roll the test specimen into a thread about 1/8 inch in diameter on a smooth surface or between the palm

2) If the specimen is too wet to roll easily, spread the sample out and allow to dry from evaporation.

3) Fold the threads and reroll. Re[eat until the thread crumbles when reaching a 1/8th inch diameter. Th thread will crumble at this diameter when it is near the plastic limit.

4) Note the strength and pressure required to roll the thread.

5) Lump the crumbled thread together and knead until the lump crumbles.

6) Describe the toughness of the thread in accordance with the criteria in Table 3.

DESCRIPTION OF SOIL LESS THAN 3 INCHES IN DIAMETER

MOISTURE

Dry: No moisture

Damp: Feels wet but leaves no moisture on hands.

Moist: Leaves moisture on hands.

Wet: Can squeeze water out of specimen.

CONSISTENCY (ASTM D 2488)

Cohesive:	Very Soft	Thumb will penetrate soil more than 1 inch
	Soft	Thumb will penetrate soil about 1 inch
	Firm	Thumb will indent soil about 1/4 inch
	Hard	Thumb will not indent soil but readily indented with thumbnail
	Very Hard	Thumbnail will not indent soil

DENSITY (NAVFAC DM-7.1-17)

		Relative Density	Pocket Penetrometer	Practical Guide
Cohesionless:	Very Loose	< 15 %	< .25 tsf	
	Loose	15 - 35 %	.25 - .50 tsf	Easily excavated: hand shovel
	Compact	35 - 65 %	.50 - 1.00 tsf	Difficult to excavate: hand shovel
	Dense	65 - 85 %	1.00 - 2.00 tsf	Loosen with pick to excavate: hand shovel
	Very Dense	> 85 %	2.00 - 4.00 tsf	

GRADATION

Note the percentage of material (by weight) in the three categories:

> #4	Percent larger than #4 sieve (4.76 mm)
<#4 >#200	Percent smaller than #4 sieve but larger than #200 sieve (.074 mm)
<#200	Percent smaller than #200 sieve

FIELD TESTS OF SOIL PASSING #40 SIEVE SIZE

Select a handful of soil and remove the particles larger than the No. 40 sieve (grain sizes larger than about the size of salt grains).

DRY STRENGTH

1) Select enough material to form a 1 inch diameter ball and mold the material until it has the consistency of putty, adding water if necessary.

2) Make at least three 1/2 inch diameter lumps and allow these specimens to dry in air or sun ensuring that the drying temperature does not exceed 60 degrees.

3) If the specimen contains 1/2 inch diameter natural dry lumps, these can be used in place of remolded balls

4) Test the dry strength of the lumps by attempting to crush them, using a rolling action, between the thumb and forefinger. Note the strength using the criteria in Table 1 below:

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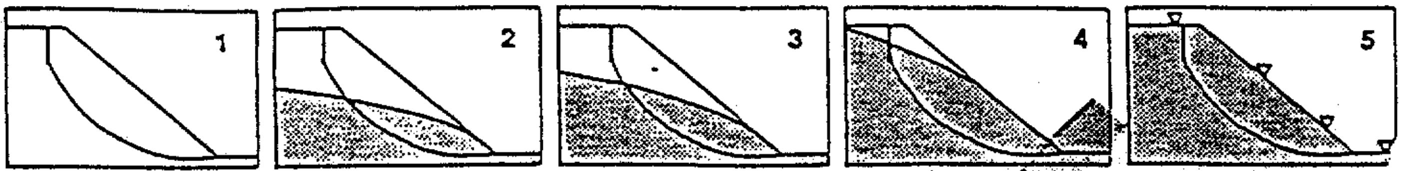
DRAFT MANUAL FOR THE DETAILED HAZARD ASSESSMENT DATA SHEET

WATER



Fully drained slope | Water emits from toe. Surface water enters upper slope at distance of 8 x Height back from toe. (8 x HL) | Water emits above toe. Surface water enters upper slope at (4 x HL) | Water emits about halfway between toe and top of cut. Surface water enters upper slope cut (2 x HL) | Saturated slope subjected to heavy surface recharge

Select number of water condition displayed on the data sheet that best describes site.

ENGINEERING SOIL UNIT DESCRIPTION

							Description of Soil <3-Inch Diameter						Field Tests of Soil < #40 Sieve			<#200 Sieve	
Soil Units	Geologic Unit	Origin	Thickness	Max. Size	Percent >3"	Percent <3"	Moisture	Consistency	Density	Gradation (optional) >#4	<#4>#200	<#200	Toughness	Dilatancy	Dry Strength	Plasticity	Classify USCS

SOIL UNIT:
Assign arbitrary letter that will represent the particular set of soil parameters described.

GEOLOGIC UNIT:
Note lithologic unit that directly underlies the soil unit, e.g. Alluvium, Till, Tuff, Basalt etc.

ORIGIN:
Note geologic origin of soil unit, e.g. Residuum, Colluvium, etc.

THICKNESS:
Give the best estimate of the range of the soil unit thickness.

MAXIMUM SIZE:
Note the maximum size of fragments greater than 3 inches.

PERCENT > 3 INCHES:
Note the percentage of material (by weight) greater than 3 inches.

PERCENT < 3 INCHES:
Note the percentage of material (by weight) greater than 3 inches.

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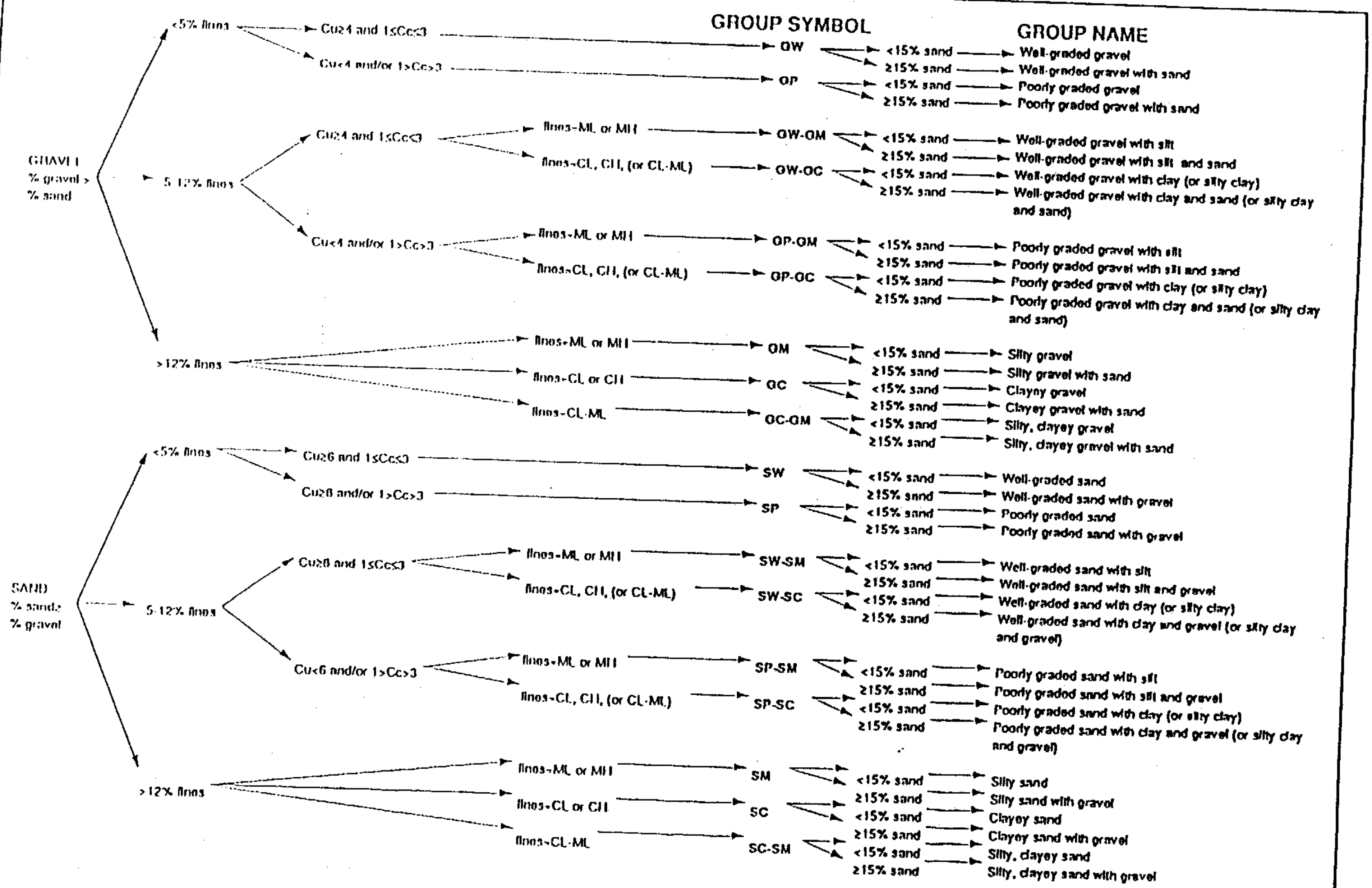

FIGURE 2

FLOW CHART FOR CLASSIFYING COARSE-GRAINED SOILS

DNR/SLOPE HAZARD/WA

PROJECT NO. 913-1121 DWG. NO. 25063 DATE 6/20/91 DRAWN CB

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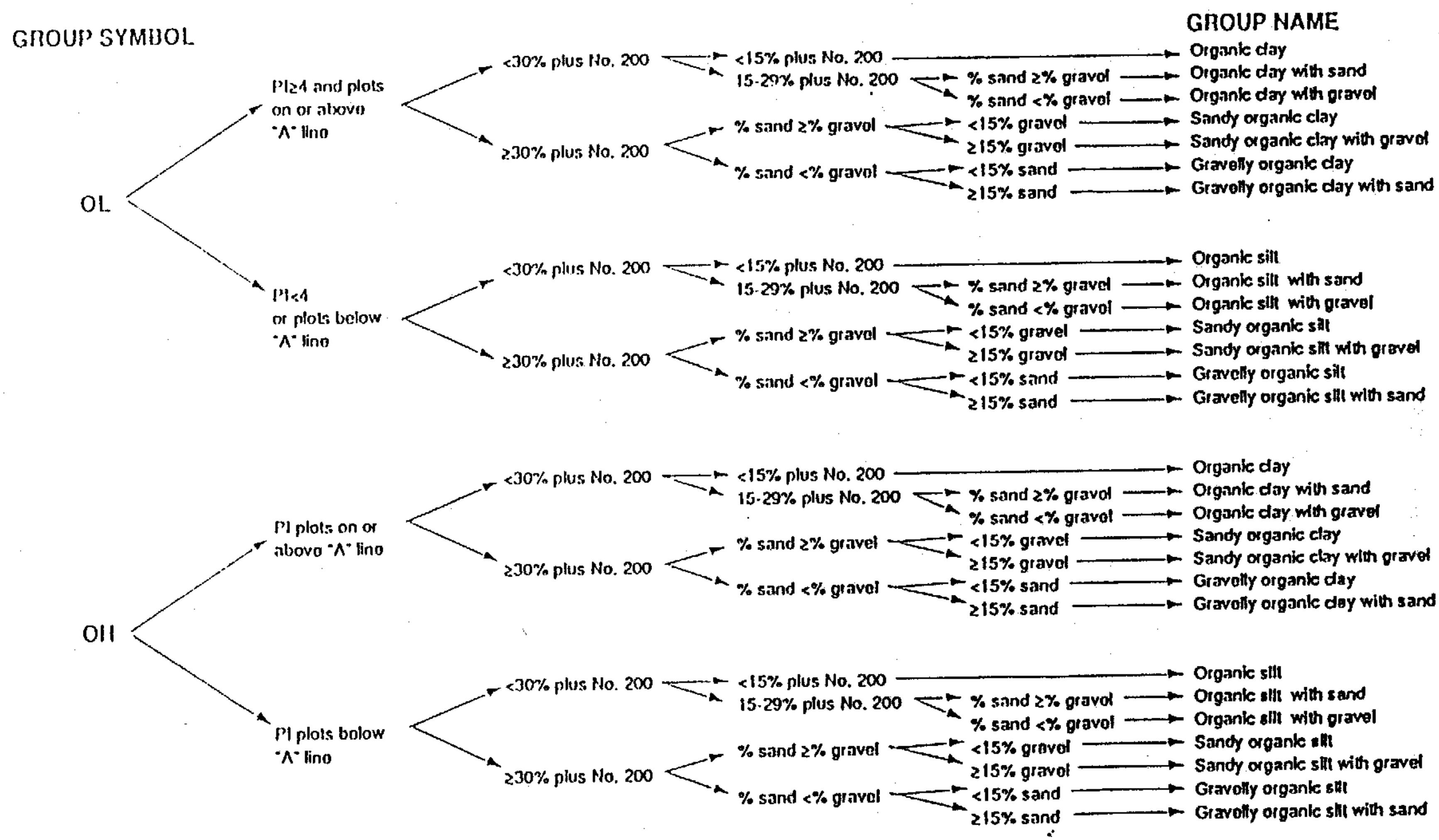

FIGURE 1b

FLOW CHART FOR CLASSIFYING ORGANIC FINE-GRAINED SOIL

DNR/SLOPE HAZARD/WA

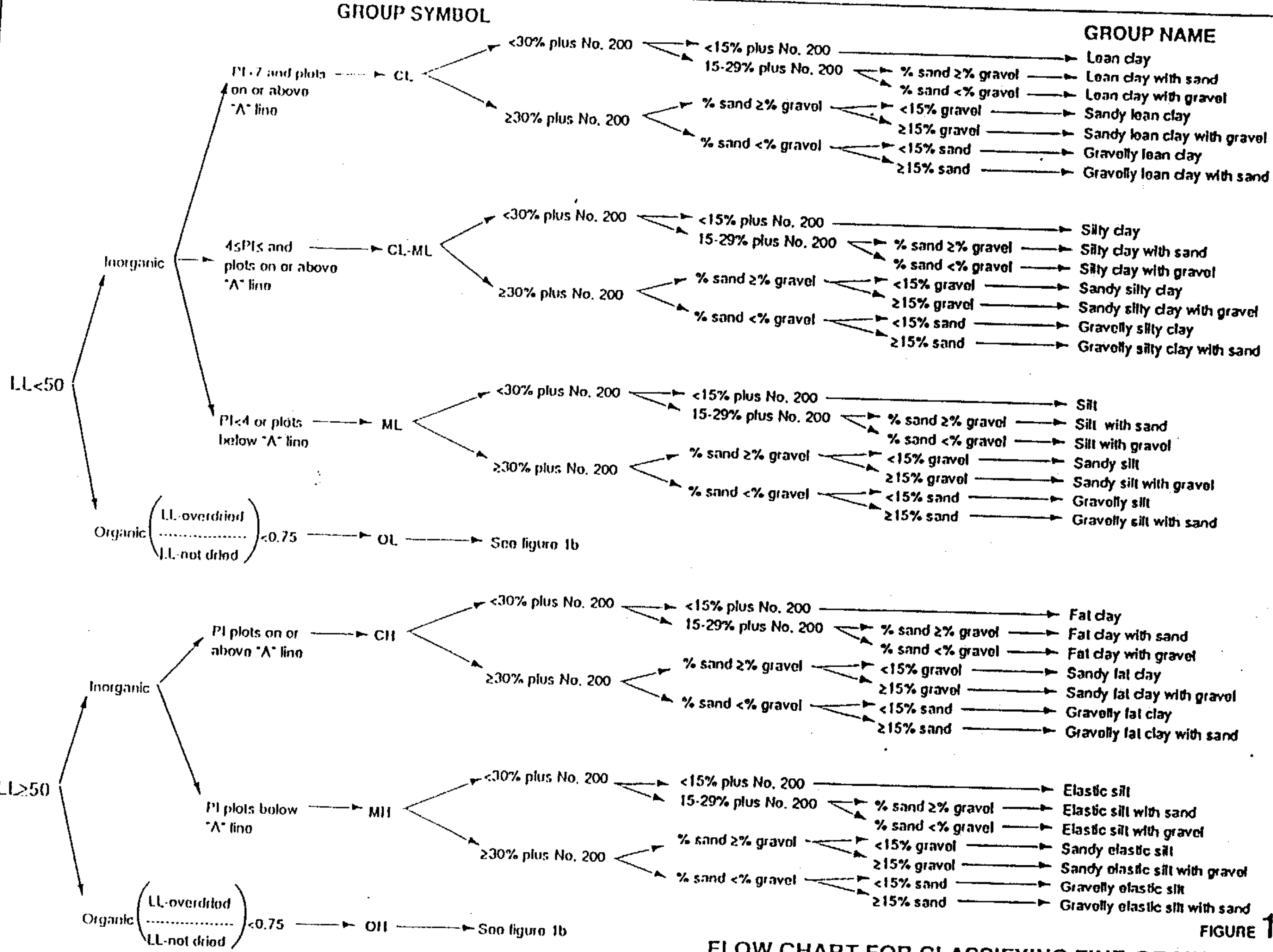

FIGURE 1a

FLOW CHART FOR CLASSIFYING FINE-GRAINED SOIL

DNR/SLOPE HAZARD/WA

PROJECT NO. 913-1121 DWG. NO. 25661 DATE 6/26/91 DRAWN CB

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Unified Soil Classification System

Criteria for Assigning Group Symbols and Names			Soil Classification	Generalized Group Descriptions
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 Sieve	CLEAN GRAVELS Less than 5% fines	GW	Well-graded Gravels
			GP	Poorly-graded gravels
		GRAVELS WITH FINES More than 12% fines	GM	Gravel and Silt Mixtures
			GC	Gravel and Clay Mixtures
	SANDS 50% or more of coarse fraction passes No. 4 Sieve	CLEAN SANDS Less than 5% fines	SW	Well-graded Sands
			SP	Poorly-graded Sands
		SANDS WITH FINES More than 12% fines	SM	Sand and Silt Mixtures
			SC	Sand and Clay Mixtures
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	SILTS AND CLAYS Liquid limit less than 50	INORGANIC	CL	Low-plasticity Clays
			ML	Non-plastic and Low-Plasticity Silts
		ORGANIC	OL	Non-plastic and Low-Plasticity Organic Clays Non-plastic and Low-Plasticity Organic Silts
	SILTS AND CLAYS Liquid limit greater than 50	INORGANIC	CH	High-plasticity Clays
			MH	High-plasticity Silts
		ORGANIC	OH	High-plasticity Organic Clays High-plasticity Organic Silts
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	Peat

Component Definitions by Gradation

Component	Size Range
Boulders	Above 12 in.
Cobbles	3 in. to 12 in.
Gravel	3 in. to No. 4 (4.76mm)
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 (4.76mm)
Sand	No. 4 (4.76mm) to No. 200 (0.074mm)
Coarse sand	No. 4 (4.76mm) to No. 10 (2.0mm)
Medium sand	No. 10 (2.0mm) to No. 40 (0.42mm)
Fine sand	No. 40 (0.42mm) to No. 200 (0.074mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

INTACT MATERIAL GRADE

Indicate the grade, as listed below, which corresponds to the rock unit and set.

GRADE	ROCK DESCRIPTION	FIELD IDENTIFICATION
R0	Extremely Weak	Indented by thumbnail.
R1	Very Weak	Crumbles under firm blows with point of geologist hammer, can b peeled by a pocket knife.
R2	Weak	Can be peeled by a pocket knife with difficulty, shallow indentatio made by firm blow with point of geologist hammer.
R3	Medium Strong	Cannot be scraped or peeled with a pocket knife, specimen can b fractured with single blow of geologist hammer.
R4	Strong	Specimen requires more than one blow of geologist hammer to fractur
R5	Very Strong	Specimen requires many blows of geologist hammer to fracture.
R6	Extremely Strong	Specimen can only be chipped with geologist hammer.

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USCS CLASSIFICATION

The soil material should be classified according to the system presented in Appendix A. In addition, the inorganic fine grained soil can be identified using the result of the descriptions applied from Dry Strength, Dilatancy and Toughness, see Table 6 below:

SOIL SYMBOL	DRY STRENGTH	DILATANCY	TOUGHNESS
ML	NONE TO LOW	SLOW TO RAPID	LOW OR THREAD CANNOT BE FORMED
CL	MEDIUM TO HIGH	NONE TO SLOW	MEDIUM
MH	LOW TO MEDIUM	NONE TO SLOW	LOW TO MEDIUM
CH	HIGH TO VERY HIGH	NONE	HIGH

ENGINEERING ROCK UNIT

ROCK UNIT:

Assign an arbitrary letter for each lithologic type.

SET NUMBER:

Assign a sequential number for each fracture set in the lithologic unit.

CHARACTER OF DISCONTINUITY

FAILURE MECHANISM:

Mark the box which best describes the mechanism of failure.

DISCONTINUITY DIP (degrees):

Mark the box which best brackets the majority of the discontinuity dip direction into the cut of feature.

PERSISTENCE

Mark the box which best brackets the range for most of the spacing of the set.

SURFACE PROPERTIES

Mark the box which best describes the dominant surface texture of the discontinuities of the set.

3) Fold the threads and reroll. Re[eat until the thread crumbles when reaching a 1/8th inch diameter. The thread will crumble at this diameter when it is near the plastic limit.

4) Note the strength and pressure required to roll the thread.

5) Lump the crumbled thread together and knead until the lump crumbles.

6) Describe the toughness of the thread in accordance with the criteria in Table 3.

Description	Criteria for Describing Toughness
LOW	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
MEDIUM	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
HIGH	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

ESTIMATE OF PLASTICITY ON SOIL PASSING THE #200 SIEVE

PLASTICITY

1) Describe the plasticity of the material in accordance with the criteria shown in Table 4.

Description	Criteria for Describing Plasticity
NONPLASTIC	A 1/8 inch diameter thread cannot be rolled at any water content.
LOW	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
MEDIUM	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
HIGH	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Description	Criteria for Describing the Reaction of Pressure to the Dry Sample
NONE	Crumbles into powder with mere hand pressure.
LOW	Crumbles into powder with some finger pressure.
MEDIUM	Breaks into pieces or crumbles with considerable finger pressure.
HIGH	Cannot be broken with finger pressure. Breaks into pieces between thumb and a hard surface.
VERY HIGH	Cannot be broken between the thumb and a hard surface.

DILATENCY

1) Select material to mold into a 1/2 inch diameter ball, adding water if necessary until it is soft but not sticky.

2) Smooth the ball in the palm of the hand with a small spatula.

3) Shake horizontally by striking the side of the hand vigorously against the other several times. Note the reaction of water appearing on the surface of the soil.

4) Squeeze the sample by closing the hand or pinching the soil between the fingers. Note the reaction in accordance with the criteria in Table 2. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Description	Criteria for Describing Dilatancy
NONE	No visible change in the specimen.
SLOW	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing.
RAPID	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

TOUGHNESS

1) Roll the test specimen into a thread about 1/8 inch in diameter on a smooth surface or between the palms.

2) If the specimen is too wet to roll easily, spread the sample out and allow to dry from evaporation.

CONSISTENCY (ASTM D 2488)

Cohesive:	Very Soft	Thumb will penetrate soil more than 1 inch
	Soft	Thumb will penetrate soil about 1 inch
	Firm	Thumb will indent soil about 1/4 inch
	Hard	Thumb will not indent soil but readily indented with thumbnail
	Very Hard	Thumbnail will not indent soil

DENSITY (NAVFAC DM-7.1-17)		Relative Density	Pocket Penetrometer	Practical Guide
Cohesionless:	Very Loose	< 15 %	< .25 tsf	
	Loose	15 - 35 %	.25 - .50 tsf	Easily excavated: hand shovel
	Compact	35 - 65 %	.50 - 1.00 tsf	Difficult to excavate: hand shovel
	Dense	65 - 85 %	1.00 - 2.00 tsf	Loosen with pick to excavate: hand shovel
	Very Dense	> 85 %	2.00 - 4.00 tsf	

GRADATION

Note the percentage of material (by weight) in the three categories:

> #4	Percent larger than #4 sieve (4.76 mm)
<#4 >#200	Percent smaller than #4 sieve but larger than #200 sieve (.074 mm)
<#200	Percent smaller than #200 sieve

FIELD TESTS OF SOIL PASSING #40 SIEVE SIZE

Select a handful of soil and remove the particles larger than the No. 40 sieve (grain sizes larger than about the size of salt grains).

DRY STRENGTH

1) Select enough material to form a 1 inch diameter ball and mold the material until it has the consistency of putty, adding water if necessary.

2) Make at least three 1/2 inch diameter lumps and allow these specimens to dry in air or sun ensuring that the drying temperature does not exceed 60 degrees.

3) If the specimen contains 1/2 inch diameter natural dry lumps, these can be used in place of remolded balls.

4) Test the dry strength of the lumps by attempting to crush them, using a rolling action, between the thumb and forefinger. Note the strength using the criteria in Table 1 below:

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DRAFT MANUAL FOR THE DETAILED HAZARD ASSESSMENT DATA SHEET

WATER

Select number of water condition displayed on the data sheet that best describes site.

ENGINEERING SOIL UNIT DESCRIPTION

SOIL UNIT:

Assign arbitrary letter that will represent the particular set of soil parameters described.

GEOLOGIC UNIT:

Note lithologic unit that directly underlies the soil unit, e.g. Alluvium, Till, Tuff, Basalt etc.

ORIGIN:

Note geologic origin of soil unit, e.g. Residuum, Colluvium, etc.

THICKNESS:

Give the best estimate of the range of the soil unit thickness.

MAXIMUM SIZE:

Note the maximum size of fragments greater than 3 inches.

PERCENT > 3 INCHES:

Note the percentage of material (by weight) greater than 3 inches.

PERCENT < 3 INCHES:

Note the percentage of material (by weight) greater than 3 inches.

DESCRIPTION OF SOIL LESS THAN 3 INCHES IN DIAMETER

MOISTURE

Dry: No moisture
Damp: Feels wet but leaves no moisture on hands.
Moist: Leaves moisture on hands.
Wet: Can squeeze water out of specimen.

APPENDIX G

DETAILED SLOPE HAZARD ASSESSMENT DATA SHEET USERS MANUAL

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DETAILED SLOPE HAZARD ASSESSMENT

(See Manual for explanation)

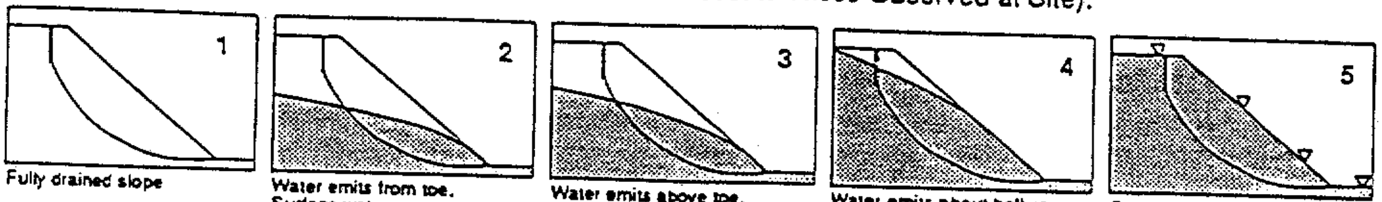
(Alternative #2)

Assessor Name ______________________ Date __________

1. LOCATION OF DESCRIBED SEGMENT OR FEATURE

Township ________ Range ________ Section ________ Segment No. ________ Site No. ________

2. WATER (Circle Number Corresponding to Condition Closest to Those Observed at Site):



1. Fully drained slope
2. Water emits from toe. Surface water enters upper slope at distance of 8 x Height back from toe. (8 x Ht.)
3. Water emits above toe. Surface water enters upper slope at (4 x Ht.)
4. Water emits about halfway between toe and top of cut. Surface water enters upper slope cut (2 x Ht.)
5. Saturated slope subjected to heavy surface recharge

3. ENGINEERING SOIL UNIT

Soil Units	Geologic Unit	Origin	Thickness	Max. Size	Percent >3"	Percent <3"	Description of Soil <3-inch Diameter: Moisture	Consistency	Density	Gradation (%) (optional)			Field Tests of Soil < #40 Sieve: Toughness	Dilatancy	Dry Strength	<#200 Sieve: Plasticity	Classify USCS
										>#4	<#4>#200	<#200					

4. ENGINEERING ROCK UNIT

Rock Units	Set Number	Character of Discontinuity: Failure Mechanism			Discontinuity Dip (degrees)				Persistence (feet)			Surface Properties			Intact Material Grade
		Planar	Wedge	Topple	0-25	25-50	50-75	>75	<10	10-30	>30	Smooth/Sheared	Rough	V. Rough/Irregular	

5. ATTACH PLAN MAP AND CROSS-SECTIONS

DETAILED SLOPE HAZARD ASSESSMENT (Alternative #1)

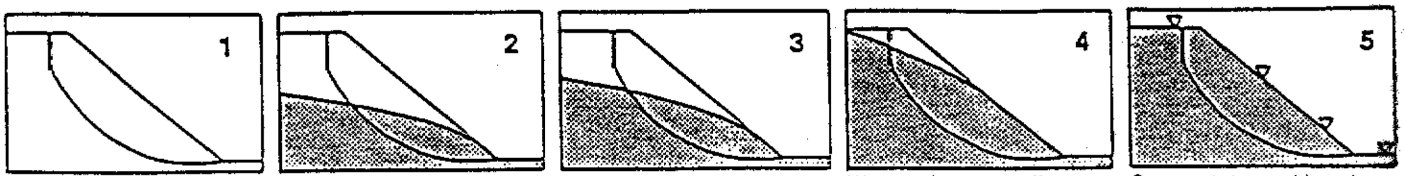
(See Manual for explanation)

Assessor Name ______________________________ Date __________

1. *LOCATION OF DESCRIBED SEGMENT OR FEATURE*

Township ________ Range ________ Section ________ Segment No. ________ Site No. ________

2. *WATER* (Circle Number Corresponding to Condition Closest to Those Observed at Site):



1: Fully drained slope

2: Water emits from toe. Surface water enters upper slope at distance of 8 x Height back from toe (8 x Ht.).

3: Water emits above toe. Surface water enters upper slope at (4 x Ht.).

4: Water emits about halfway between toe and top of cut. Surface water enters upper slope cut at (2 x Ht.).

5: Saturated slope subjected to heavy surface recharge.

3. *STRENGTH*

Geologic Unit Associated with Soil __________

Engineering Soil Unit (Average Over Segment, Section or Site)

Origin __________

Estimated thickness __________ft.

Maximum Fragment Size __________in.

Percent > 3 in. ______ < 3 in. ______

Description of Soil > 3 in. Diameter (Circle One):

Moisture	Dry	Damp	Moist	Wet		
Consistency (Cohesive)	V. Soft	Soft	Firm	Stiff	V. Stiff	Hard
Density (Cohesionless)	V. Loose	Loose	Compact	Dense	V. Dense	

Estimated Gradation ______% > #4 sieve

______% < #4 sieve > #200 sieve

______% < #200 sieve

Field Test on Soil < #4 sieve (.425mm) (Circle One):

Toughness	None	Slight	Medium	High
Dilatency	Quick	Slow	V. Slow	None
Dry Strength	None	Slight	Medium	High

Plasticity (< #200 sieve) npl bpl apl

Unified Soil Classsification: ______

Engineering Rock Unit (Average Over Segment, Section or Site)

		Character of Discontinuity											Surface Properties			Intact Material Grade
Rock Units	Set Number	Failure Mechanism			Discontinuity Dip (degrees)				Persistence (feet)							
		Planar	Wedge	Topple	0-25	25-50	50-75	>75	<10	10-30	>30	Smooth/Sheared	Rough	V. Rough/Irregular		

APPENDIX F

DETAILED SLOPE HAZARD ASSESSMENT DATA SHEET

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Zero order basin: A slope unit that joins a slope and a stream, a seasonally shifting conjunctive area of hill-slope and fluvial process, an area where subsurface storm runoff appears on the ground as saturated overland flow and the area becomes part of a stream during a storm.

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Full Bench: Practice of constructing a road prism entirely as a cutslope. Usually used where earth fill slopes will not remain at an angle corresponding to a 1.5H:1V slope or rock fill slope will not remain at an angle corresponding to a 1.25H:1V slope.

Landslide: A general term for a variety of mass movement types that involve down slope transport of "naturally occurring" earth materials. The term describes several types of mass movement which may or may not include actual sliding as a mechanism for ground failure.

Mass Movement: A progressive process in which the shear strength of a material decreases relative to the shear stress until resisting forces are less than the driving forces.

Right-of-Way: Land, property or property interest, usually in a strip, acquired for or devoted to transportational purposes.

Road Prism: Portion of the road right-of-way that contains the area used to construct the cutslope, roadbed and fill slope.

Rock (engineering): Reserved for earth material the cannot be excavated with earth moving equipment. Note: Usually must be ripped with bull dozer tongs or blasted during excavation.

Self Balanced: Construction practice where the material from the cutslope can be used for the road fill.

Sidecast Construction: Practice of placing excavated material by incidental or deliberate spillage, bladeing or end dumping during road construction and used as part of the road fill. Usually not allowed on slopes steeper than 55 percent.

Sidecast Waste: Identical to sidecast construction except that the material is wasted down slope and not used as road fill.

Slope Failure: Usually refers to mass movement related to human activities.

Slope Stability: Condition of a natural or constructed slope describing the resistance to failure. Note: This is often evaluated by applying mathematics to model the mass movement or to model site conditions and arrive at a relative "Factor of Safety."

Soil (engineering): The Unified Soil Classification System defines soil group names by material grain sizes that are less than or equal to 3 inches. Note: The term "soil" can also include material that can be excavated with earth moving equipment and placed in regular lifts during construction.

Subgrade: The top surface of the roadbed on which sub-base, base, surfacing, pavement of layers of similar layers of materials are placed.

The numbered locations shown on the sketch are listed below:

- 1.) ridge top
- 2.) midslope
- 3.) valley or drainage bottom
- 4.) lower slope break
- 5.) upper slope break
- 6.) plateau
- 7.) side slope adjacent to stream

General Landforms (FIGURE 2)

Slope Shape (FIGURE 3)

The road prism shape will help determine the geometry of the site. the numbers indicated on the typical section are located at the position on the slope of the required measurement. The actual measurement or estimate of the value should be indicated in the blanks on the right hand side of the page.

Road Prism Shape (FIGURE 4)

Many factors relating to the existing failure, if present, should be estimated. These include, the approximate year that the existing failure initially occurred, length, width and average depth of the material involved in movement. The failure type should be entered for the corresponding location in the road prism where the failure is located. The main material type and mechanism are coded on the left hand side of this section. Select the number that matches the best estimate of the material (at the failed surface) and mechanism.

2.2.5 Water (FIGURE 5)

2.2.6 Strength (FIGURE 6)

3. SPECIALISTS FIELD ASSESSMENT

Collect Site Specific Information
Assess Need for Geotechnical/Experts Input

4. DEFINITIONS

Colluvium: Earth material that has moved or deposited mainly through forces of gravity.

Debris: Earth material composed various mixtures of soil, rock fragments and organic material. In construction, all non-usable natural material produced by clearing, grubbing or roadside cleanup.

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2. DATA COLLECTION

This section is intended as a supplement to help further explain the items included in the hazard assessment data sheet.

2.2.1 Location of Site

The location of the described road segment or mass movement feature, mileposts that bracket the feature, elevation and reference maps are needed to help track the site location.

2.2.2 Site History

It is important to track site construction and repair history. Preventive maintenance priorities may be improved and logging and construction activities can often be adjusted to improve adverse trends. Enter the following information as it applies to the road or site:

- Road Construction: approximate year that the road was initially constructed (first cut and fill on slope).
- Past Wildfire: year or years that wildfire(s) burned vegetation adjacent to site.
- Logging: year or years that logging was conducted
- Distance to Timber Cut: distance in feet to nearest logged area up slope and down slope of site.
- Road Construction Type: circle one or more descriptions of the construction along road segment or at site, or list other.
- Road Maintenance History: Years or average frequency that the listed maintenance occurred, or list other.

2.2.3 Performance in Road Prism

This portion of the data sheet is intended to provide information on the location and severity of the slope condition. The number(s) corresponding to stability feature from the list on the right should be placed next to the road prism locations listed on the left in order to match the appropriate feature with the correct location.

2.2.4 Geometry

This section is included to provide in formation on the relative slope position of the site, road prism shape, geometry and type of failure. In order to indicate the correct location of the site, circle the numbered location on the profile sketch that best shows the location.

(TABLE 1: Selection of Landslide Types from Varnes (1978).)

1.4 General Indicators of Mass Movement

Mass movement is influenced by many site factors however, most of these can be related one of the three following characteristics:

- geometry of the failure mass
- pore pressures at the failure surface
- strength of the material

The actual parameters defining these site features are often the subject of great effort in studies of mass movement. The reliability of the assessment of slope hazards hinges on the level of quality achieved in collecting site parameters. In other words, the better the data, the more reliable the assessment.

Several tools are available that have proven useful for indicating potential or existing slope hazards. One must be familiar with the site and specifically focus attention on the area in terms of mass movement processes. In the office, prior to a field oriented evaluation, one can use several tools to help in this "attention focusing" process. Such tools may include air photos, topographic maps, geologic/soil/hazard maps and literature or information on file. One should not forget that others, such as road maintenance crews, may have experience in the area and offer valuable insight about the area in question. Though after some field experience is gained the use of these tools may seem repetitive it is still considered a necessary step prior to making field observations.

Several general observations made in the field can help an assessor to key into mass movement processes that may exist. With-in the road prism, surface erosion, ravel, drainage conditions and evidence of movement can indicate mass movement. On "undeveloped" ground slope shape in terms of concentrating surface water, hummocky topography, springs, seepage and vegetative cover may help to indicate areas where further work is necessary. Many of the important features considered essential to slope hazard assessment are included on the data sheet and are further explained in Section 3 of this guide.

1.5 Collection of Data

The collection of information for a slope hazard assessment can be accomplished at sites of existing failures, along designated lines, such as roads and in larger areas, to assess failure potential. Information collected at existing failures can help in the design for fixing the problem, and can be stored for use as a history tracking system. Information from designated road segments or areas can help to delineate regions that require more intensive effort. Data from "undeveloped" areas can help the land manager make decisions for long range planning.

MANUAL FOR THE PRELIMINARY SLOPE HAZARD ASSESSMENT ON FORESTED LAND

REVISED June 28, 1991

1. INTRODUCTION

1.1 Purpose and Scope

The purpose of this guide to slope hazard assessment on forested land is to explain the type of information necessary to evaluate potential or existing slope hazards and mass movement. This manual is designed to help the assessor conduct a preliminary hazard assessment and provide input to the decision making process for hazard reduction.

We have assumed that collection of information on forested land will be done on two levels. First, the site or area under consideration will be reviewed "on-the-ground" by forestry personnel who will not have specific training mass movement or earth science. These personnel, typically forest engineers, road locators and maintenance personnel, will use the hazard assessment data sheet to help them build a data base of their land. The area under consideration will be ranked by hazard and will lead the assessor to an analysis of the consequences. If the consequences are considered to have a high level of importance then a data collected

Several definitions will prove useful for relating information about slope hazards. There are many terms, and defined types of slope hazards. The terms often referred to in this guide relating to mass movement on forested land are included in Section 5 of this manual. The Landslide Classification presented by Varnes (1978) is presented as a guide to help define movement and material types involved in mass movement features.

1.2 Definition of Selected Terms

The term "mass movement" in this guide refers to a progressive process in which the shear strength of a material decreases relative to the shear stress until resisting forces are less than the driving forces. A "landslide" is a general term applied to a variety of mass movement types that involve down slope transport of "naturally occurring" earth materials. "Landslide" includes several types of mass movement which may or may not include actual sliding as a mechanism for ground failure. The term "slope stability" covers a condition describing the resistance to failure of a natural or constructed inclined surface.

1.3 Landslide Classification

The classification system presented by Varnes (1978) is depicted by a selection of figures in Table 1. This classification system helps to define the type or types of movement and general material involved at the time of the failure. The primary category for classification is Type of Movement and Type of Material is a secondary category. It is important to note that the type of movement relates to the motion of the failure mass and the type of material is based of the state of the material mass before the initial movement.

APPENDIX E

PRELIMINARY SLOPE HAZARD ASSESSMENT DATA SHEET USERS MANUAL

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Existing Failure:

Failure (Yr.)________ Length ________ ft. Width________ ft. Average Depth of Scarp (Perpendicular to Slope) ________ ft.

Failure Type(s) (Indicate Numbered Selection from Material/Mechanism Lists):

Potential Selections	
Material Type	Failure Mechanism
A. Rock	1. Fall
B. Soil	2. Flow
C. Debris	3. Slide
	4. Topple
	5. Avalanche

(Mat/Mech)

___/___ Natural Slope (Above Road)

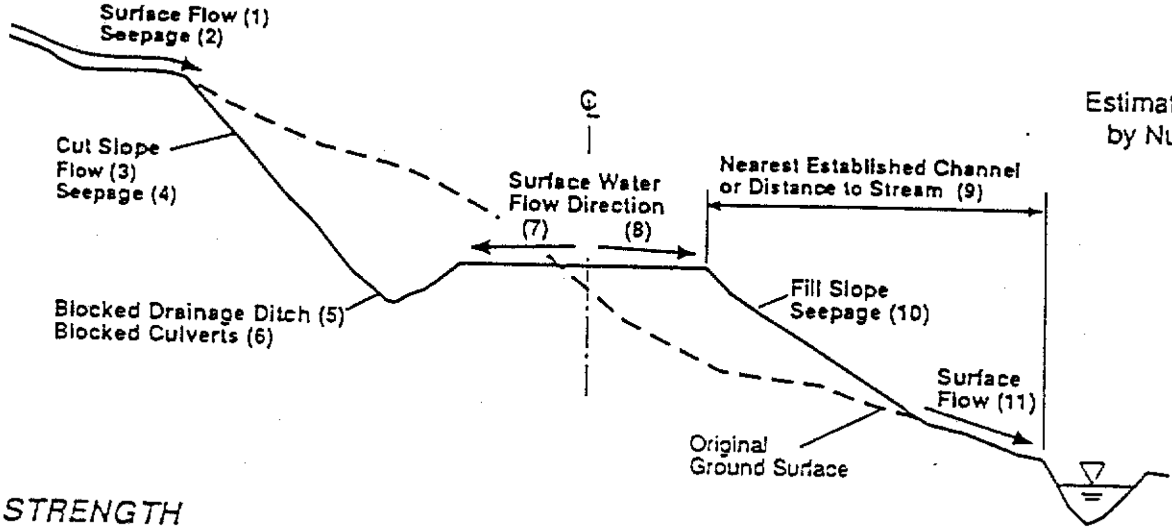
___/___ Cut Slope

___/___ Ditch

___/___ Fill Slope

___/___ Natural Slope (Below Road)

5. *WATER*



Circle Yes/No or
Estimated Measurement
by Numbers Indicated:

Y / N (1)

Y / N (2)

Y / N (3)

Y / N (4)

Y / N (5)

Y / N (6)

Y / N (7)

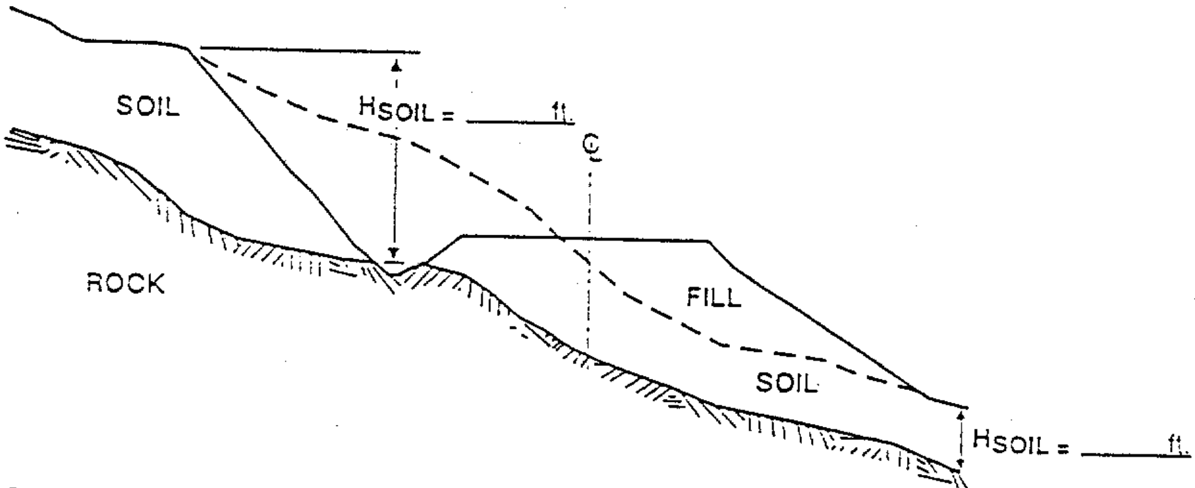
Y / N (8)

_____ ft. (9)

Y / N (10)

Y / N (11)

6. *STRENGTH*



Soil Composition (Circle if Present, Give Percentages if Possible):

Rock Fragments _____% Sand Size Fraction _____% Silt/Clay Size Fraction _____%

Fill Composition (Circle if Present, Give Percentage if Possible):

Rock Fragments _____% Sand Size Fraction _____% Silt/Clay Size Fraction _____% Organics _____%

Rock (Circle One): Massive Moderate Fracturing Heavy Fracturing

Blasting _____% Rippable _____% Excavated _____%

PRELIMINARY SLOPE HAZARD ASSESSMENT

(See Manual for explanation)

Assessor Name ____________________

Date __________ Weather Conditions ____________________

Sketch of Road and Segment or Feature Location in Section

Township _____ Range _____
Section _____ Segment No. _____

1. *LOCATION OF DESCRIBED SEGMENT OR FEATURE*

Road Number/Name ____________________

Milepost or Milepost Start and End ____________________

Elevation (ft.- msl) ____________________

Reference Map(s) or Other Reference Name ____________________

____

2. *SITE HISTORY*

Original Road Constr. (Yr.) _____ Road Reconstr. (Yr.) _____ Past Wildfire (Yr.) _____ Logging (Yr.) _____

Distance to Timber Cut (up slope) _____ ft. (down slope) _____ ft.

Road Construction Type (Circle one or more):

Drill and Blast | Reinforced Earth Fill | Through-Cut | Sidecast | Full Bench
Embankment Fill | Self Balance | Light-Weight Fill | Stream Crossing | Other (attac description)

Road Maintenance History (Indicate Year(s) or average years between activity):

Ditch Clean-out _____ | Subgrade reinforcement _____ | Resurfacing _____ | Fill repair _____
Regrade of Road _____ | Culvert repair/replacement _____ | Cutslope repair _____ | Other _____ (attach des

3. *CURRENT PERFORMANCE IN ROAD PRISM* (Indicate Numbered Selection(s) from List):

Potential Selections List

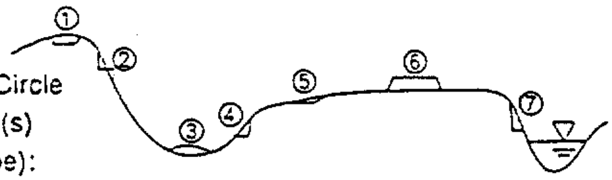
1. Stable
2. Organic decomposition
3. Surface erosion
4. Surface ravel
5. Poor drainage
6. Blocked drainage
7. Tension cracks
8. Subsidence
9. Slope failure (See 4.)
10. Other __________

Number(s)

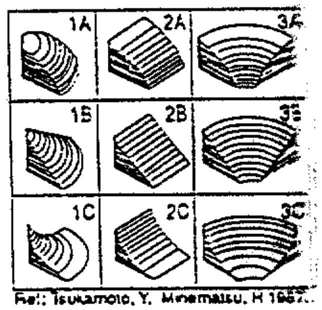
_____ Natural Slope (Above Rd.)
_____ Cut Slope
_____ Ditch
_____ Running Surface/Roadway
_____ Fill Slope
_____ Subgrade
_____ Natural Slope (Below Rd.)

4. *GEOMETRY*

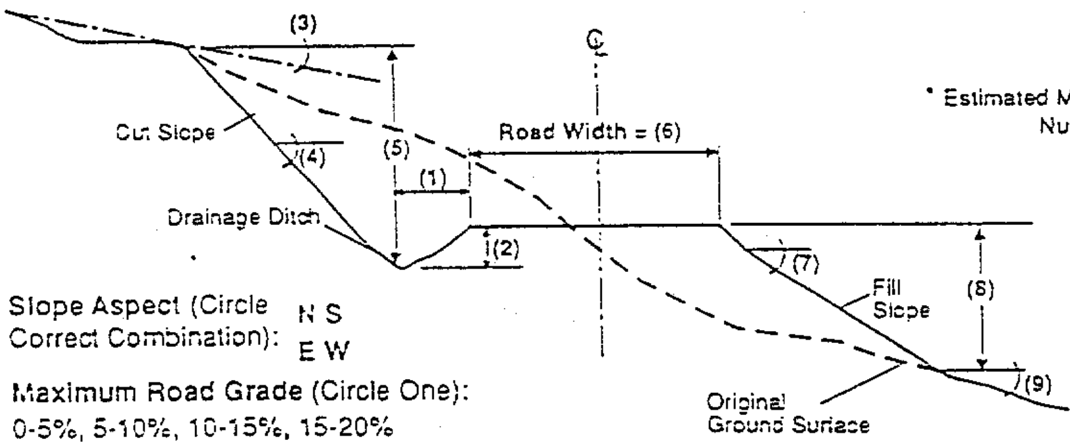
General Landform (Circle Approximate Position(s) of Road on Landscape):



Slope Shapes (Circle One):



Road Prism Shapes (Indicate maximum values *)



* Estimated Measurements by Numbers Indicated:

_____ ft. (1
_____ ft. (2
_____ % (3
_____ % (4
_____ ft. (5
_____ ft. (6
_____ % (7
_____ ft. (8
_____ % (9

Slope Aspect (Circle Correct Combination): N S E W

Maximum Road Grade (Circle One):
0-5%, 5-10%, 10-15%, 15-20%

Side One

APPENDIX D

PRELIMINARY SLOPE HAZARD ASSESSMENT DATA SHEET

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MEMORANDUM

TO: FILE
N. Norrish
B. Burk
B. Roberds

June 28, 1991

FR: W.C. Adams

RE: BIBLIOGRAPHY OF LITERATURE REVIEW FOR SHAMW PROJECT
LITERATURE CONCERNING MASS MOVEMENT INVENTORIES AND THEIR APPLICATION TO THE FOREST INDUSTRY (Our ref: 913-1121)

This is a bibliography to summarize the contents of our literature search concerning mass movement as applied to management of forested land in the Western United States and Canada. It is not a comprehensive listing of all literature on slope stability, mass movement or landslide inventories.

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DRAFT REPORT ON

PHASE I
DESIGN OF A
SLOPE HAZARD ASSESSMENT SYSTEM
FOR
WASHINGTON'S FORESTED LAND

DRAFT

Submitted to:

WASHINGTON STATE DEPARTMENT
OF NATURAL RESOURCES

Distribution:

THE RECOMMENDATIONS OF THIS REPORT REFLECT THE VIEWS OF THE AUTHORS AND NOT NECESSARILY THOSE OF THE T/F/W COOPERATIVE MONITORING, EVALUATION AND RESEARCH (CMER) SEDIMENT, HYDROLOGY AND MASS WASTING STEERING COMMITTEE (SHAMW).

June 28, 1991

913-1121

Golder Associates

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1. INTRODUCTION

The Sediment, Hydrology and Mass Wasting Steering Committee (SHAMW), with the Department of Natural Resources (DNR) acting as the contracting agency, entered into an agreement with Golder Associates Inc. to provide guidelines for the evaluation of mass movement on forested land. Our proposal dated January 25, 1991, presented our technical and philosophical approach to the project including the delineation of two separate work phases. Phase 1 was proposed to consider primarily the development of field methods for slope stability hazard assessment. Phase 2 of the project was intended to develop a field verification method for the assessment methods and to develop a decision analysis methodology.

This draft report presents the results of the Phase 1 study and makes recommendations for the second phase. Although significant interaction has taken place between Golder and various SHAMW, DNR and forest company representatives, it must be recognized that certain decisions with regard to the style and degree of implementation of the methodologies presented herein can only be made by the ultimate users. Within this report we have pointed out where further input from SHAMW/DNR is required to select among viable alternatives before the final product is developed.

The specific objective of Phase 1 of the project as identified in the agreement was "to provide methods to identify and rate potential site specific slope stability problems associated with proposed or existing forest roads, including an objective and accountable methodology for collecting and organizing road system information that encourages preventive road management." In conducting the Phase 1 program to meet this objective, we have:

- Attended meetings with SHAMW
- Conducted interviews with technical personnel
- Developed the preliminary slope hazard assessment data sheet and manual
- Drafted a detailed slope hazard assessment data sheet and manual
- Made recommendations for implementing the assessment

For ease of reference, the report has been structured so that Sections 2 and 3 summarize background information collected from an extensive literature search, by way of an internal technical forum, and through interviews with forestry personnel. Section 4 describes the rationale behind the development of a two stage slope assessment methodology. Sections 5 and 6 deal, respectively, with the preliminary and detailed slope hazard assessments. Section 7 summarizes several alternatives for the application of decision analysis techniques to the preventive maintenance of forest road systems. A work plan for Phase 2 of the project is outlined in Section 8 while Section 9 summarizes the salient points of the Phase 1 study. Supplementary data and draft assessment sheets and companion user's manuals are contained in Appendices A through G.

2. RESULTS OF TECHNICAL FORUM

A technical forum involving 14 participants was held in Redmond, Washington, on May 6, 1991, and included SHAMW members, a representative from the Washington State Department of Transportation and Golder project team members. The main topics covered during the technical forum included: 1) SHAMW goals for implementing a hazard assessment system and 2) operating requirements of a system developed by Golder. Minutes of the meeting are presented in Appendix A.

Based on discussions at the forum, it was stated that a primary objective of SHAMW in developing a hazard assessment system was to have a rational and technically defensible methodology for forestry road managers. After implementation and subsequent to the inevitable slope failure, the managers will have a bona fide and trackable system for the decisions which were taken relative to the site which experienced the failure. Some of the secondary objectives for the hazard assessment system which were discussed included the following:

- Apply to old and new road systems.
- Apply to all mass movement within the road prism.
- Develop an inventory of stability-related parameters (i.e. surrogates) for all assessed road segments. The inventory must be flexible enough to be incrementally implemented at a variety of scales (eg. specific road, drainage basin or district).
- Be implemented by individuals with a range of technical expertise ("generalists" and "specialists").
- Consider environmental, political and cost consequences.
- Offer a way to rate hazards and complete hazard mapping.
- Calculate a probability of failure.
- Direct road managers to give greater attention to higher "risk" road segments (i.e. targeting function)

In addition, the ultimate system was to be functional, user friendly, verifiable and have an expandable data base system that could be readily updated. It was agreed that the system would exclude road construction or material source development.

The SHAMW committee representatives at the forum also developed the following prioritized list of consequences that should be considered in a decision analysis system:

- Environmental: proximity to streams, wildlife habitat, fish species (ranked), botanical species, type of material, existing stream quality, stream category and fisheries.
- Safety: road traffic/recreation, dwellings and utilities
- Political issues: credibility to the public and regulators as stewards of the forests
- Clean-up costs: proximity to waste/borrow areas, material type, design materials, required resources (equipment type), weather/season.
- Loss of Service: traffic/type and alternative routes.
- Loss of Product: size of failure, loss of resource, loss of access, service area, timber and non-timber resources.

The forum participants concluded that it was necessary to conduct interviews of the SHAMW members' technical and professional staff to collect insight covering several topics discussed at the forum. The interviews would promote a discussion of the needs for a slope hazard assessment system and its method of implementation.

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3. SURVEY OF TECHNICAL STAFF AND LITERATURE

3.1 Interviews

Golder conducted a survey of eight representatives of companies or agencies involved with forest management in order to help compile a list of data that might be used in a preliminary slope hazard assessment. Golder drafted a list of questions for the interviews to help guide the discussions with technical personnel representing Crown Pacific, Department of Natural Resources (DNR), Weyerhaeuser, Plum Creek Timber and U.S. Forest Service. The interview questions are included in Appendix B.

During the interview process, the following advantages of the proposed slope hazard assessment methodology were offered to Golder:

- Beneficial to transfer information from experienced managers to new managers.
- Strong interest in an inventory which would track stability problems associated with construction history.
- Data base inventory should have a graphical option to produce graphical summaries and field maps.
- Useful to prioritize maintenance.

Some of the disadvantages mentioned during the interviews included:

- Failure occurrences are too random to be predicted by general computer models.
- Larger slides have greatest consequences and are not predictable.
- No replacement for on-site evaluations.
- Do not expect maintenance workers to use any type of data collection work sheet.
- Not able to improve on current methods for preventing or fixing stability problems.
- Very difficult to collect the necessary data to build a comprehensive data base.
- Risk/hazard rating system would supply the regulators with more ammunition to "hammer" or, at a minimum, slow down the industry.
- Concern that regulators who use such a system may be inexperienced and extrapolate the system beyond the confidence of the input data.

A summary of the technical forum and the responses to the interviews was presented by Golder to the DNR annual engineering meeting on May 23, 1991 held at Winthrop, Washington. One of the key observations at the meeting was that the inventory aspect of the project would be very beneficial to forest road managers in that it would document historical events and systematize the collection of basic data relative to the hazard potential along forest roads. Concern was voiced about the decision analysis aspect of the project in that the regulators might rely totally on the recommendations produced by the system and not have the flexibility to make independent site specific judgements.

3.2 Literature Search

In addition to the interviews, we also completed a literature review of studies dealing with mass movement on forested slopes in the Western United States and Canada. This review further enhanced our understanding about the site characteristics that influence mass movement on forested slopes. In summary, the following salient points were derived from the literature:

- Descriptions of several studies and inventories of landslides on forested land and the conclusions concerning the occurrence and resulting changes to land management in response to the studies.

- Lists of the kinds of information that could be collected during a survey of past or potential damage.

- The DNR's outline for their planned Hazard Zonation including:

  - testing the current slope hazard rating system,
  - develop and/or adapt alternative systems of zonation,
  - compare current systems' validity, verifiability, replicability, flexibility, informative value, time and costs
  - produce results, appraise potential for adapting to GIS, explain changes to current zonation system.

- Current methods used by the Washington State Department of Transportation to identify and mitigate slope hazards, including the data sheet used for input into the expert system depicted on the system flow charts.

- A reference to 43 landslide inventories in northern California, Oregon, Idaho, Washington and Canada. Topics included:

  - Area involved in landslide
  - Amount of sliding occurring as a result of roads and timber harvest
  - Opportunities for control
  - Methods for quantifying potential
  - Impacts and recovery from mass movement
  - Recommended database needs for future landslide inventories

The complete listing of our literature review is included in the bibliography of Appendix C.

4. DEVELOPMENT OF FIELD ASSESSMENT METHODOLOGY

4.1 Assumptions

In order to develop the field assessment methodology, it has been necessary to make multiple assumptions with regard to the nature of the road systems under consideration, the magnitude of stability problems, the types of available data and the varied qualifications of the field personnel who will undertake the assessments. The assumptions which have been made are based on our understanding of forest practices gained from the interviews, our previous experience and the technical forum process. The key assumptions are discussed below:

- Qualifications of Field Personnel: It is expected that personnel forming at least two levels of expertise will perform field assessments. For the purposes of this program, we have deemed these individuals as "generalists" and "specialists". The generalist is defined as a person with extensive forest road experience, usually in a maintenance capacity, but usually without formal training in the geological or geotechnical fields. The specialist category represents a geologist or geotechnical engineer with suitable experience in the evaluation of slope stability for roads.

- Character of Road System: Field assessment data will be collected along linear elements or corridors in the form of existing roads or P-lines for proposed roads. Data will generally not be collected in a traditional plan-view mapping format for the preliminary field assessment work.

- Background Data: Topographic, climatic and other data bases are anticipated to be available or to be developed. It is assumed that this information can be incorporated during the "office analyses" and no effort has been made to incorporate such data at the field assessment stage.

4.2 Objectives

The objectives of the field assessment stage are as follows:

- To systematize the data collection procedure so that data quality is as uniform as possible.

- To collect geotechnical data in a "surrogate" form appropriate to the qualifications of the field personnel.

- To facilitate implementation at whatever level the agency or company desires (specific road, drainage basin, district etc.)

- To act as a targeting mechanism so that attention is directed to those critical areas requiring more study.
- To be compatible with existing data base resources (GIS systems) and to be amenable to computerized storage, analysis, retrieval and display.
- To be field verifiable.
- To serve as a field inventory of historical problems along forest roads and thereby transfer experience to successive road managers.
- To facilitate prediction of future stability problems and thereby serve as input to decision analyses for maintenance management.

4.3 Methodology

To facilitate the assumptions and objectives discussed above, we have developed a two-stage system for slope hazard assessment. The preliminary assessment is intended to be a rapid evaluation exercise of a general road system subdivided into relatively large segments and to be carried out by generalists. The preliminary assessment will serve as a screening mechanism for a large amount of data that will target those critical areas that require more study in the form of a detailed stability assessment. The latter would be undertaken by specialists and would comprise a more thorough evaluation of segments or sub-segments defined in the preliminary assessment. The following sections discuss the specifics of the preliminary and detailed slope hazard assessments.

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5. PRELIMINARY SLOPE HAZARD ASSESSMENT

The purpose of preliminary slope hazard assessments is to provide a systematic approach for non-geotechnical personnel to collect information relevant to failure history, road performance, site geometry, water conditions and material strength parameters. The assessment is assumed to be carried out by field personnel with little formal training in geology or geotechnical engineering. The information will be recorded on the preliminary slope hazard assessment data sheet, Appendix D. This data is designed for use along existing/proposed road segments or at specific failure sites. The information will serve as a "screening tool" to help concenhate the efforts of land managers, maintenance operations and geotechnical specialists to areas of historical or particularly high hazard. It is our intent to use the preliminary information to provide a rating to each site or area derived from weighted values applied to specific items of the data sheet.

The first draft of the data sheet was presented to the SHAMW technical forum on June 14, 1991, to discuss the content of the data sheet, possible improvements and areas for further work.

We also began to draft pertinent sections of the preliminary slope hazard assessment user's manual that will accompany the data sheet. The final draft of the manual will be provided after the preliminary data sheet has been finalized. An outline for the preliminary slope hazard assessment data sheet users' manual is included in Appendix E. We expect the preliminary data sheet to be finalized after the results of the "field test case" are compiled during the second phase of this project.

6. DETAILED SLOPE HAZARD ASSESSMENT

6.1 Objectives

The purpose of the detailed slope hazard assessment is to provide a common evaluation approach for a "specialist" trained in earth science or geotechnical engineering. The data will be collected from areas or specific sites, and used to determine the relative potential for mass movement on a given slope or to build an information base on existing mass movement. The potential for failure will be evaluated using:

- Easily obtained background information (from various data bases)
- Existing site specific information
- Slope hazard rating (from the preliminary assessment)
- Detailed geotechnical information

The DNR is currently developing guidelines for detailed slope hazard work in order to test one or more methods of slope hazard zonation. These guides have provided a basis for the proposed detailed assessment; for reference see "Road Surveys - Information Needs and Slope-Stability Hazard Zonation Pilot Project Draft Work Plan by Brunengo, 1990".

A first draft of the detailed slope hazard assessment data sheet is supplied in Appendix F. The outline for the companion manual is included in Appendix G.

6.2 Philosophical Approach

During our deliberations for the detailed slope hazard assessment methodology, it became apparent that two distinct approaches were possible. In the first of these, the specialists collect data with a view to the typical cross-section for a field designated road segment. In the second alternative, data is collected in a more traditional plan-view mapping format. For the purposes of the discussion which follows these approaches will be termed the "cross-section" and "map" formats. The concepts and advantages and disadvantages of each format are presented in the following discussion.

6.2.1 Cross-Section Format

Using the cross-section format, the detailed hazard assessment methodology would be an extension of that for the preliminary assessment. The implementation is envisioned as follows. Based upon the preliminary assessments, a series of road segments are targeted as "high" hazard intervals requiring further study. This would trigger the detailed assessment to determine the relative priority of the various segments and to plan cost-effective remediation strategies. After review of the preliminary assessments and any available background information, the specialist carries out a field evaluation of each segment. The initial focus is to review the appropriateness of the segment definition. If unsuitable, the specialist subdivides or otherwise reallocates additional subsections and completes a preliminary hazard assessment sheet for each new subsection so defined. The reallocation would probably relate to the specialists' better appreciation for the aerial distribution of contrasting geologic units which the assessor should document by way of a corridor map for the road segment. For each of the new subsegments, the specialist gathers specific additional information based on the detailed hazard assessment sheet for this format, as presented in Appendix F, Alternative 1. The specialists' skills would be required to make certain field judgements as to the "controlling" stratigraphic, geohydrologic and material strength conditions within the subsegment. This data is then entered to the data base for an "automated" determination of the relative probabilities of a discrete number of prescribed failure modes. These probabilities are then analyzed in combination with the site specific consequences of failure to determine the "risk" of failure and ultimately the cost-benefit of alternative remediation schemes as discussed in Section 7.

6.2.2 Map Format

Using the map format, the preliminary hazard assessment will be used as a screening tool that directs the specialist to the appropriate road system locations requiring further investigation. The specialist will use any pertinent information on the preliminary hazard assessment forms, however, the specialist will be free to disregard the previously selected segment boundaries.

This format requires on the specialist to select and obtain a base to use in mapping. This base may be a conventional vertical aerial photograph, orthophotograph or a topographic map. Care will need to be taken to ensure that the base map is compatible with the media used in any central compilations of data such as a GIS system or photograph overlay system. Once the base for mapping has been selected, a corridor map will be prepared that documents the distribution of engineering units (consisting of groups of one or more geologic units with similar engineering properties), surface hydrologic characteristics and landform types, particularly those related to slope stability. During this process information will be collected on the thickness of each engineering unit as well as index engineering properties such as relative density, stiffness, gradation, and plasticity. A first draft of the detailed assessment sheet for the map format is given in Appendix F as Alternative 2.

After the field data have been acquired other pertinent information such as other geologic mapping data, climatic data, and vegetation mapping will be overlain on the field mapping data and road segments will be defined based on the similarity of hazard conditions (this may also be defined in the field based on the mapped data alone). Once the segments are located, representative cross-sections will be drawn for each segment. This data can then be entered into a data base and relative failure mode probabilities determined as described in Section 6.2.1.

6.2.3 Discussion

The advantages and disadvantages of each format for the execution of detailed slope hazard assessments are presented below:

Cross-Section Format

- Advantages
  - Segment allocation is correlative between the preliminary and detailed assessments.
  - All data is collected in a format amenable to automated evaluation.
  - Field assessment is rapid and many key decisions are made in the field.
- Disadvantages
  - Presumes that the specialist is adequately qualified to assign segments or subsegments in the field based on the preliminary assessment and on a relatively quick appraisal of the site.
  - Requires a significant degree of "homogenization" of geologic conditions in order to represent the segment with a limited number of parameters.

Map Format

- Advantages
  - Allocation of segments and development of cross-sections in the detailed assessment is more rigorous and can be documented.
  - Data is collected in a format amenable to inclusion in a GIS database.
- Disadvantages
  - Segment allocation is not correlative between the preliminary and detailed assessments.
  - The map data collection effort is less systematized and may be less amenable to automated processing.

At this stage of program development, Golder has not had the opportunity to discuss these alternative formats for the detailed field assessments with SHAMW members. For the purposes of this Stage 1 report, we have presented both options as a basis for further discussion during Phase 2 of the program. One of the primary issues which the SHAMW members should consider in this context is the ultimate use of the data, specifically whether a decision system is to be incorporated in the final product. Section 7.0 discusses possible systems based on our understanding of the project gained during Phase 1.

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7. DECISION ANALYSIS SYSTEM

Several options exist regarding the decision analysis methodology to adopt for this project. The appropriate option to select depends on the specific application as well as on the available analytical resources. The possible applications consist of the following:

- Development of a slope inventory, with a "rating" determined for each slope. This rating would indicate the level of concern for each slope. Such a "rated" inventory would allow for a rough prioritization of the attention to pay on each slope. The highest rated slopes would subsequently be treated individually in the "standard" way, e.g., investigation, analysis, and design based on judgement, whereas the lowest rated slopes would essentially be ignored. The rating could be based on either "hazards" or "risks". The hazard rating would indicate the probability of various types of failure modes occurring, whereas the risk rating would indicate the probability of various types of failure modes occurring in conjunction with the potential consequences if such failures do occur. The decision approaches for a site inventory by hazard ranking and by risk ranking are illustrated in Figure 1 a) and b), respectively.

- Identification of optimized design/maintenance schemes. A decision methodology could be developed which would select the appropriate design/maintenance alternative for each slope, based on the most cost efficient minimization of the risks involved, possibly subject to budgetary constraints. This would require an assessment of the risks associated with each slope, i.e., the probability of various types of failure modes occurring and the potential consequences if such failure modes do occur, as well as an assessment of the cost effectiveness of available design/maintenance alternatives in reducing those risks. Such "risk management" could be applied to individual slopes or to a set of slopes. For a set of slopes, the most efficient program in reducing the risks associated with all of the slopes would be identified for any specified budget.

It is presumed that the resources for implementing the selected decision methodology are limited, especially with respect to the availability of technical "specialists". Hence, the methodology should strive to make the most efficient use of technical specialists, using less specialized staff (i.e., "generalists") as much as possible. It is thus anticipated that the data required to conduct a preliminary site hazard assessment will be obtained (primarily in the field) by generalists. Based on this information, the hazard (or probability of various failure modes occurring) will be inferred through established algorithms. Depending on the specific application (as discussed above), as well as on the availability of technical specialists, the primary options for subsequent steps are as follows:

- For optimizing the design/maintenance activities for an individual slope, the primary option is whether to conduct site consequence assessments before or after the detailed site hazard assessments by the technical specialists. Such site consequence assessments can be largely conducted by generalists in the office. Based on site consequence assessments, some slopes may be screened out and not require a detailed site hazard assessment, thus reducing the amount of work requiring technical specialists. A secondary option is whether to: (a) explicitly assess the cost effectiveness of the available design/maintenance alternatives the (by the technical specialist) in order to calculate the probable consequences of each alternative as the basis for deciding among them; or (b) implicitly evaluate the available design/maintenance alternatives and to select the best alternative, based solely on the judgement of the technical specialist. The possible decision approaches for this case are illustrated in Figure 2.

- For optimizing the program of design/maintenance activities for a set of slopes, the primary option is whether to evaluate specific programs or to optimize among all possible programs. In the first case, the various alternative programs (each consisting of a specific activity for each slope) must be identified and then explicitly evaluated in terms of the probable costs and consequences combined over all of the slopes. The program with the best probable consequences, which is also within budget, would then be selected. Identification of the various programs and the assessments of the probable consequences for each activity for each slope in a program (as discussed above) would involve significant effort by technical specialists. In the second case, the cost effectiveness of each activity applied to each slope would first be assessed (primarily by technical specialists, as discussed above). This cost effectiveness would be expressed in terms of the change in the combined consequences over all slopes. The optimum combination of activities for each slope can then be determined automatically for each budget level (or other constraint) by constrained optimization routines. This part would not require technical specialists, although they should review the results. The possible decision approaches for this case are illustrated in Figure 3.

The decision approach selected will in turn determine the appropriate type, quality and quantity of information which must be obtained. It is desirable to collect and process as little information as possible, especially from the field, to minimize costs and effort. However, in order to make better decisions, it is desirable to use as much information as possible. Clearly, tradeoffs must be made between these two objectives, so that the optimum amount of information is obtained and used.

8. WORK PLAN FOR PHASE 2

8.1 Scope

The following tasks are proposed for consideration in Phase 2 of the Slope Hazard Project:

Task 1 Internal Technical Forum

A second one-day internal technical forum will be held to present the draft Preliminary and Detailed Slope Hazard Assessment forms to a cross-section of public agency and private representatives. Specific discussion of the Detailed Assessment Form will provide Golder with guidance relative to the format in which specialists can be utilized to collect field data. The forum should also examine the ultimate implementation of the program and the extent to which decision analysis should be incorporated.

Task 2 Field Verification

Field verification of the assessment methodology is integral to the development of the hazard assessment techniques which will be utilized. It is proposed that a two-day workshop be held at a forestry camp in proximity to a road system with a range of stability and forest conditions. The work session would be organized to have all participants, including Golder representatives, rate an interval of roads through the Preliminary Slope Hazard Assessment forms. Referring to the manuals, these assessments will be compiled and compared in an open forum to identify weaknesses or ambiguities in the process, forms and manuals. Having completed the Preliminary Assessments, a set of Detailed Assessments would be carried out by specialists on specific segments rated to have a high hazard. A similar process of group analysis will be undertaken to refine the methodology and documentation.

It is recommended that 12 to 15 representatives of private companies and public agencies participate in the field verification session. These representatives should include individuals who would be considered generalists and specialists. It is anticipated that Golder will have 3 or 4 participants in the workshop.

Task 3 Finalize Field Assessment Methodology

As a result of the second internal technical forum and the field verification workshop, revisions to the field assessment methodology will be required. Under Task 3, the preliminary and detailed assessment sheets and the companion field manuals will be finalized.

Task 4 Inventory Development

A computer data base should be developed which will represent an inventory of the Preliminary and Detailed Field Assessments. It is envisioned that this system would be fully integrated with other data bases developed by State or Federal agencies. It is proposed that a working committee, comprised of road management personnel and Golder representatives, be established to oversee the development of this computer-based system. This will ensure that a user-compatible system is produced.

The deliverables from this task would require development of a database which, depending on the strategy adopted, could include the following capabilities:

- Assignment of a hazard rating to each mapped segment based on the results of a preliminary assessment or, if available, detailed assessment.
- Adaptability to incorporate and analyze data from parallel GIS sources.
- Preparation of summary reports based upon interrogation criteria such as hazard rating, previous instability, location, etc.
- On-screen display and analysis of hazard rating data.
- Plotting of maps which illustrate hazard rating.
- For those critical areas that are rated as high hazard:
  - estimation of the probability of failure for a preset number of failure mechanisms.
  - incorporation of consequence of failure data for each segment where available.
  - estimation of risk for each segment.

The software for the inventory management would be developed to the level of a highly professional product suitable for presentation to senior management.

Task 5 Decision Analysis Methodology

Depending on the approach that DNR and SHAMW chooses to adopt regarding the application of decision analysis, the following may be necessary regarding:

- Hazards
  - Development of an algorithm(s) for assigning a hazard rating to a mapped segment, e.g., based on the results of a preliminary slope hazard assessment, and specification of a threshold of concern.
  - Development of an algorithm(s) for estimating the probability of various failure modes for a mapped segment, e.g., based on the results of a detailed slope hazard assessment.

- Consequences

  - Development of a consequence assessment sheet for each mapped segment and an algorithm for assigning a risk rating to a mapped segment, e.g., based on the results of the consequence assessment, and specification of a threshold of concern.

  - Development of an algorithm(s) for estimating the probability of various consequences for each failure mode for a mapped segment, e.g., based on the results of a consequence assessment.

- Design/maintenance activities

  - Development of a cost-effectiveness assessment sheet for various design/maintenance alternatives applied to a mapped segment.

  - Development of an algorithm(s) for estimating the changes in the probability of various failure modes and in the probability of various consequences for each design/maintenance alternative if applied to a mapped segment, e.g., based on the results of the cost-effectiveness assessment.

- Optimization

  - Specification of tradeoffs and preferences among consequences.

  - Development of a system model for estimating the consequences combined over all mapped segments, considering the possible changes due design/maintenance activities, and for making tradeoffs among the various consequences (e.g., determination of a "figure of merit").

  - Application of a constrained optimization algorithm for determining the optimum program (e.g., maximum "figure of merit") for any specified budget.

Task 6 Decision Analysis Verification

If a decision analysis process is implemented in Phase 2, a verification program should be developed to test it. This verification would include the determination of consequences of failure at a specific site, and the determination of the cost effectiveness of various remediation schemes. Verification of this nature is difficult without a significant lapse of time with a preventive maintenance program in place. The best short-term alternative may be to "back-analyze" the maintenance that has been performed, or should have been performed, on a section of road with a significant history of stability problems.

8.2 Level of Effort

The level of effort to accomplish the tasks recommended for Phase 2 is dependent upon the direction and degree of implementation which DNR and SHAMW elects to adopt. However, we have developed a tentative level of effort and cost in Table 1 which assumes a full implementation of the tasks we have proposed. This estimate does not include direct costs such as computing time nor does it include the development of a full-fledged GIS. For preliminary planning, direct costs should add approximately ten percent to the estimated total labor costs in Table 1. Based upon review of this draft Phase 1 report, this estimate can be revised prior to the execution of Phase 2. Alternatively, the estimate and budget-to-complete can be updated at intervals during execution of the Phase 2 program.

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9. SUMMARY

A draft Preliminary Slope Hazard Assessment form and accompanying user's manual has been prepared and is in a format suitable for field verification.

Two alternative formats for the Detailed Slope Hazard Assessment form have been prepared. Prior to field verification, these alternatives should be critiqued by SHAMW/DNR members as part of the review of this document and in a second technical forum. Based on the input received, the form will be revised and the user's manual completed prior to field verification.

The SHAMW committee must direct Golder with regard to the desired ultimate use of the system. The alternatives include:

- A slope inventory system based on hazard (i.e., probability of failure) criteria.
- A slope inventory system based on risk (i.e., function of both probability of failure and the possible consequences of failure) criteria.
- A slope management system to assist with preventive maintenance planning, either with respect to individual slopes or a set of slopes (road system).

The selected alternative will clarify the required scope and level of effort for the Phase 2 study.

Respectfully submitted,

Norman I. Norrish
Principal

William J. Roberds
Principal

Wayne C. Adams
Project Engineer

Robert L. Burk
Associate

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Golder Associates

June 28, 1991 | 913-1121

TABLE 1

PHASE 2 PRELIMINARY LEVEL OF EFFORT AND COST ESTIMATE

Client: SHAMW/DNR
Project: Slope Hazard Assessment

Personnel	Adams	Burk	Dershowitz	Fugot	Norrish	Roberds	Support	TASK TOTAL HOURS	TASK TOTAL COST
Approximate billing rate	$55.00	$92.00	$94.00	$50.00	$118.00	$102.00	$44.00		
Task No / Description									
1 Internal Technical Forum	16	12			12	12	4	56	$4,800
2 Field Assessment Verification	40	24			24	24	8	120	$10,040
3 Finalize Field Assessment Methodology	40	16			16	8	24	104	$7,432
4 Inventory Development	80	60	40	80	40	40	60	400	$29,120
5 Decision Analysis Methodology	200	80	40	80	40	400	80	920	$75,160
6 Verification of Decision Analysis Methodology	24	8	8	16	8	40	16	120	$9,336
TOTAL HOURS BY INDIVIDUAL	400	200	88	176	140	524	192	1720	
TOTAL COST BY INDIVIDUAL	$22,000	$18,400	$8,272	$8,800	$16,520	$53,448	$8,448		$135,888

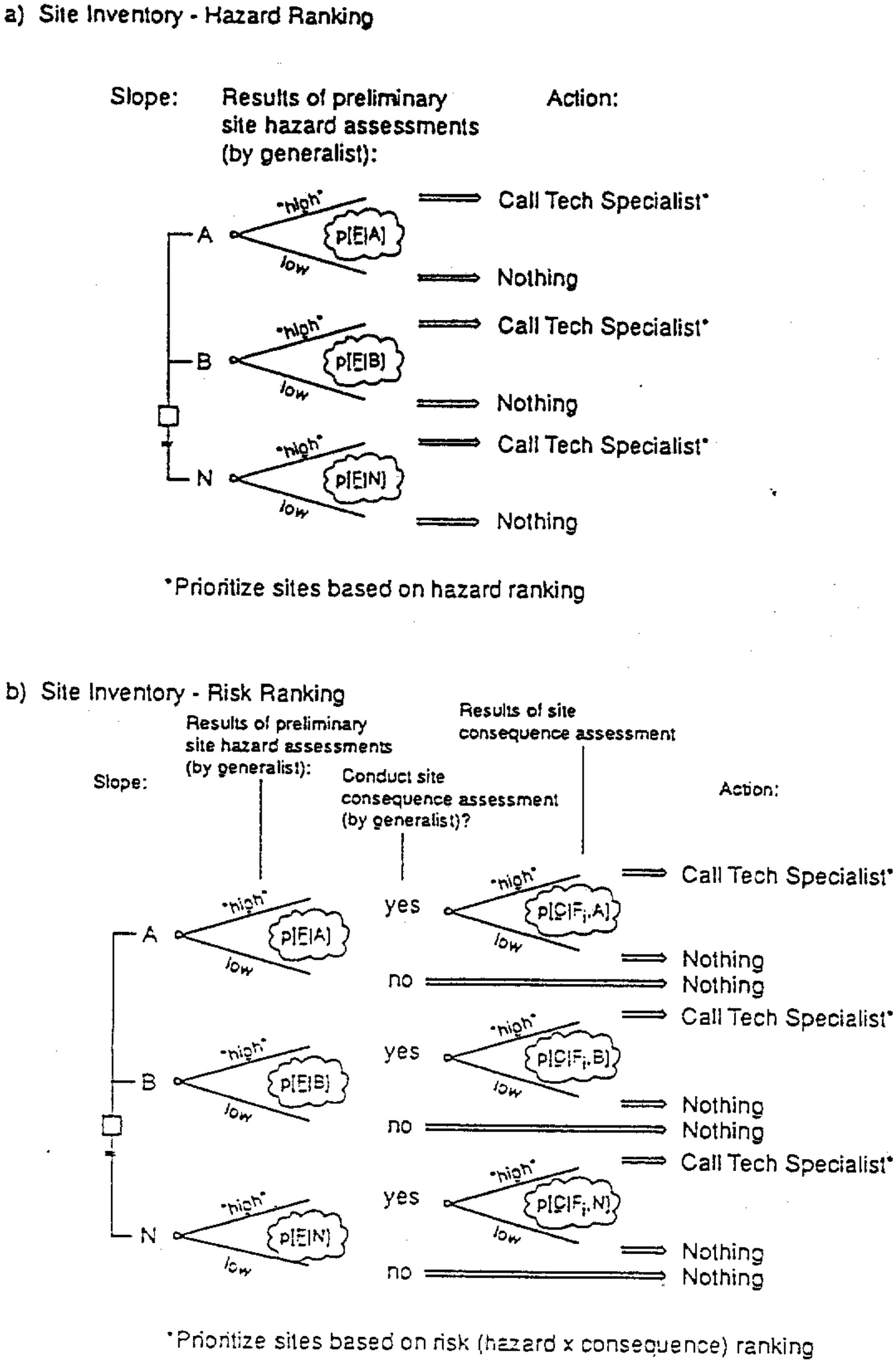

FIGURE 1
DECISION APPROACHES FOR SLOPE INVENTORY APPLICATION
DNR/SLOPE HAZARD/WA

PROJECT NO. 913 1121 DRAWING NO. 25636 DATE 6/28/91 DRAWN BY EA

Golder Associates

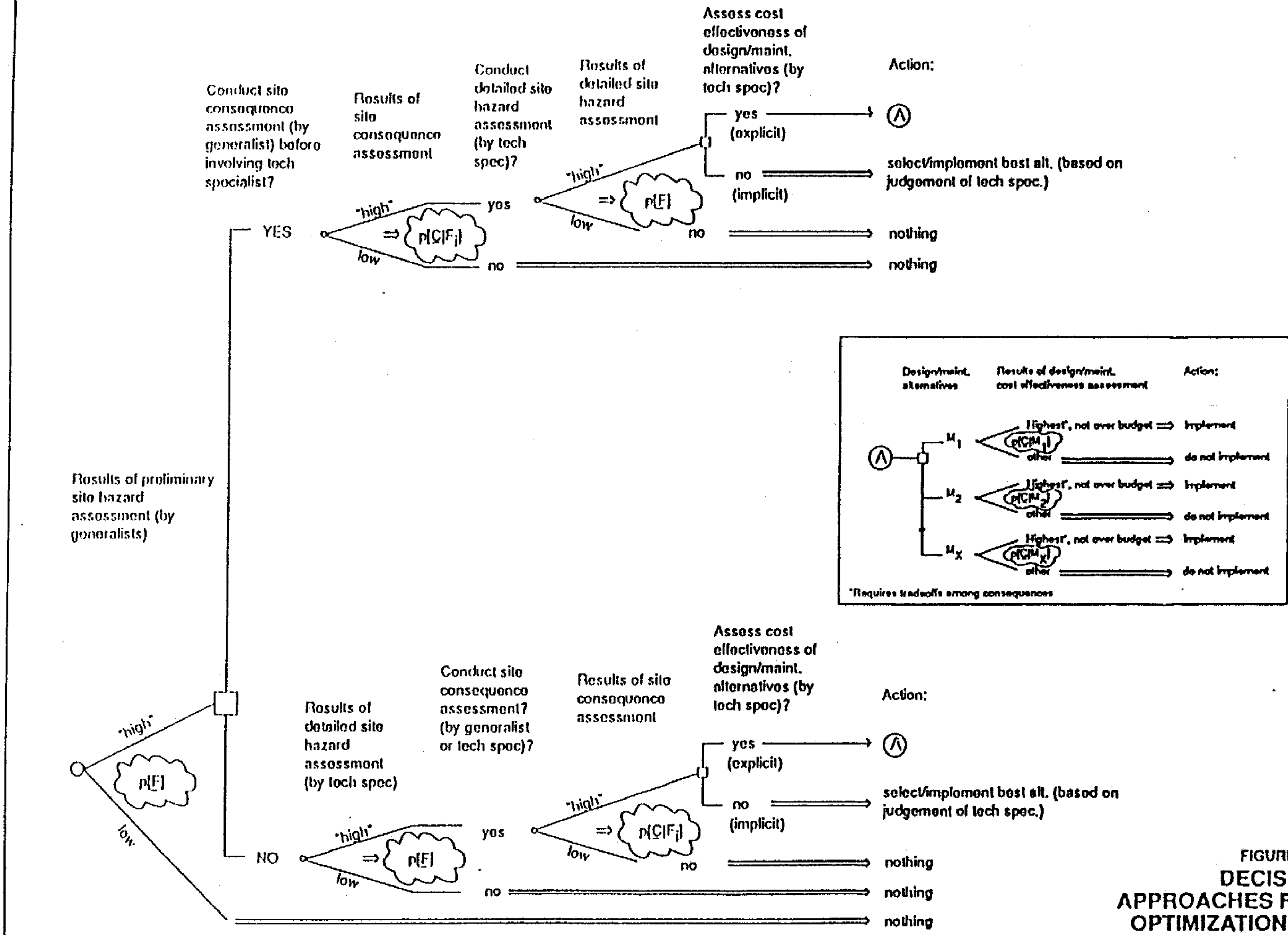

FIGURE 2
DECISION APPROACHES FOR OPTIMIZATION OF INDIVIDUAL SLOPE
DNR/SLOPE HAZARD/WA

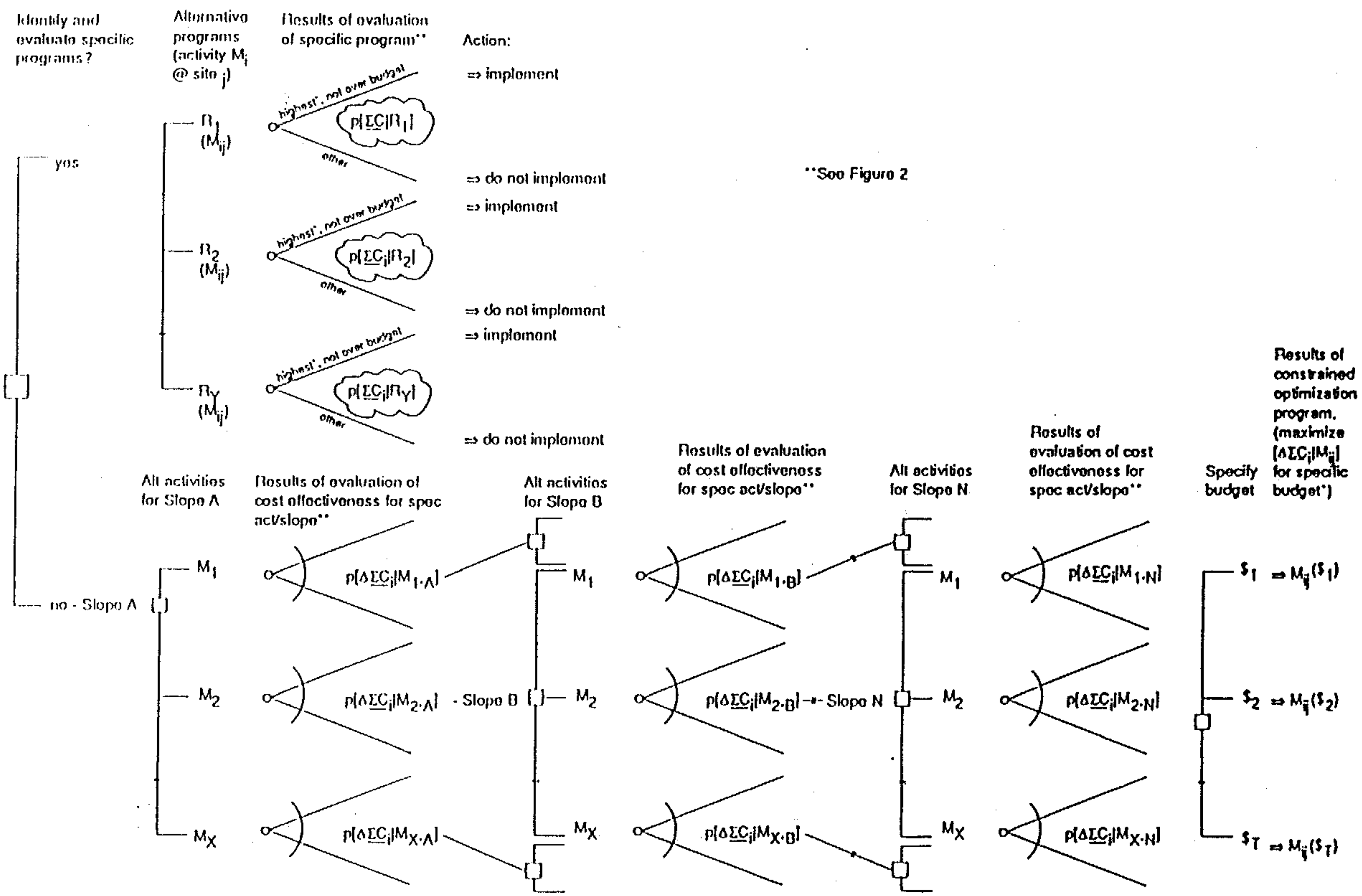

FIGURE 3
DECISION APPROACHES FOR OPTIMIZATION OF SET OF SLOPES
DNR/SLOPE HAZARD/WA

*Requires tradeoffs among consequences

APPENDIX A

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GOLDER ASSOCIATES TECHNICAL FORUM
FOR
SLOPE STABILITY HAZARD ASSESSMENT IN FOREST ROAD MANAGEMENT

MAY 6, 1991

ATTENDANCE

Bill Roberds	Golder Associates	(206) 883-0777
Norm Norrish	Golder Associates	(206) 883-0777
Wayne Adams	Golder Associates	(206) 883-0777
Marti Spencer	Dept. of Nat. Res.	(206) 825-1631
Jim Ward	Weyerhaeuser	(206) 736-8241
Jim Hurst	Dept. of Nat. Res.	(206) 753-2093
Matt Brunengo	Dept. of Nat. Res.	(206) 459-6372
Mary Raines	Citizen - SHAMW	(206) 671-6476
Kate Sullivan *	Weyerhaeuser	(206) 924-6191
Dave Beedle	Muckleshoot Tribe	(206) 825-7030
Tom Koler **	U.S.F.S.	(206) 593-6735
Duncan Wyllie	Golder Associates	(604) 879-9266
Bob Burk	Golder Associates	(206) 883-0777
Steve Lowell	W.S.D.O.T.	(206) 753-4660

* Not present at meeting after 1230

** Not present at meeting from 1200 to 1430

Meeting commenced at about 0930.

N.Norrish: Begins with self introduction of each member. Explains that this meeting is intended to be an "idea session" and not a formal presentation. Golder assumes that focus for hazard assessment is on 1) Forest or Road Manager or people with earth sciences background and 2) slope stability problems with-in the road prism.

K.Sullivan: Outlines the Timber Fish and Wildlife (TFW) organization. Explains the informal bond between the Forest Practices Board and TFW. The Forest Practices Board informally advises TFW policy by committee or on a consequences basis. TFW/CIMER/SHAMW reaches decisions by consensus, no voting. Forest Service was not initially involved or invited when the SHAMW began meeting in 1986 because members had to be able to set policy for their company. John Lowell was initially contacted to represent Forest Service Management. Golder is funded through DNR budget, project may encompass 3 to 4 years. Problems have come up with-in the TFW framework concerning failure to address policy.

T.Koler: Decision making process is based on the consequence.

K.Sullivan: SHAMW wants a product that works [easy to use] and shows that techniques are effective [in reducing hazard]. The main problems;

- to recognize [potential] hazards, field personnel need to be able to identify problems especially during road location.
- identify existing hazards. Engineers feel that they are doing a good job but as seen in the Deschutes Basin, there is a record of poor performance.

T.Koler: Issues are 1) Hazard: slope conditions (slope/road prism) and 2) Risk: potential resource damage.

K.Sullivan: First focus of product should be catastrophic events. Environmental consequences are very important.

T.Koler: Lot of rhetoric to deal with stability such as "reshape road prism" but there is no clear view on how to put road back to a "quasi-natural" slope.

N.Norrish: What are the user's qualifications?

M.Spencer: DNR-Logging Engineer, have some earth science training. Seven regions in the DNR with various levels of capability but normally the field foresters assess P-lines and locates the roads. Engineers run construction crews and maintenance.

D.Wyllie: People may know problems and their locations but not have the technical background to assess.

M.Spencer: Would like to see engineers work with road locators.

N.Norrish: Is it true that the most difficult ground is left to harvest?

K.Sullivan/M.Spencer/J.Ward: This is generally true but some stability problems re-occurring in areas already opened. Some of flatter slopes still having problems.

J.Ward: Weyerhaeuser is about 96 percent roaded, [so not too many problems will be "new ground"].

M.Raines: USFS is [realizing] a rapidly shrinking budget for maintenance [therefore] becoming more reactive to problems.

J.Hurst/K.Sullivan: Final say to act on problems rests with the district manager. Engineers are used more in a consulting role.

N.Norrish: Funded through DNR budget.

K.Sullivan: Maintenance vs. Road Design Engineering; very different managers and styles. Must design something that's attractive.

B.Burk: Has any hazard mapping been done similar to that accomplished on the Gifford Pinchot & Olympic N.F.'s?

Group: No organized mapping other than USFS.

T.Koler: Need to show managers that they can make decisions and alert the necessary experts. USFS is mostly going to a recreation base [less emphasis on forest management/timber harvest].

M.Brunengo: DNR, regulates itself, weyerhaeuser and local small outfits. Slope hazard ratings do exist: State Soil Survey. Accepted but no where near perfect. Matt is in the process of improving rating system. Currently there is no prioritized system for handling problems. Attention goes to the worst [visible] problems. Currently working in three main areas [to assess stability]:

- Redefine State Hazard Zonation
- Address stability in an "on-call" site specific manner
- Prioritize by drainage basins

J.Hurst: DNR seems to use macro approach; can't I.D. a problem until there is one.

M.Spencer: Northwest District system uses GIS for Steep Slopes/Stream Proximity/Road Proximity. They have found a very poor correlation.

T.Koler: Just a matter of scale, haven't enough information for the DNR to use the GIS effectively.

K.Sullivan: The main problem is to get away from surprises. Need to help engineers have fewer false starts by 1) read the landscape and 2) prevention oriented across scale.

B.Burk: Who do we train? Least common denominator is most effective but [must] look at what groups can do.

K.Sullivan: [replies to who will use the system]. She often hears that "only the pro's do this" instead of "the existing people have to do this". Get as many people as possible into this [system of assessment]. Shouldn't assume that [Golder] has to use the existing system. In her experience the engineers get 80% of the problems, but they need other tools [to catch the other 20% of the stability problems]. Weyerhaeuser engineers indicate mapping [as the likely other tool].

M.Spencer: Need machine operator training.

T.Koler: Must talk to road maintenance crews [to get an idea of the type and location of problems].

N.Norrish: Sounds like a Multi-Staged system is necessary. [Summarizes our 2-Phased proposal]

B.Roberds: Introduces "Current Practice."

N.Norrish: Discusses Golder CP Rail Project.

D.Wyllie: Must be able to I.D. problem and fix. It is typically not effective to do a little bit of work in several places.

S.Lowell: WSDOT I.D. all unstable slopes. They estimated that $180 million of work would be required to fix stability problems. [The biggest question was] which to fix first? Rating system was implemented; road type,traffic loads, road impedance rating, failure frequency. Prioritized for maintenance. Using an Expert System shell - Carl Hoh at W.S.U.

T.Koler: USFS Hazard Mapping is a product of three stepped planning system: Forest Plan/10 year Plan/Timber Sale. Between 10 year Plan and the Timber Sale there is a series of stability analyses.

- LEVEL I: MUSLE/WEPP, LISA or Hoek & Bray, applied to sale areas at the planning stage to from a three layered polygon system.
- LEVEL II: SARA applied to road corridors at the transportation planning stage (1"=300" typical scale).
- LEVEL III: MOSES applied to road prism (1"=10' typical scale).

Mainly work with the Soil Scientist, Biologist & Engineering Geologist. Once basin is assigned (Integrated Resource) then run hazard risk assessment.

K.Sullivan: Can use an inventory with levels of analysis to get funding. Weyerhaeuser would be willing to supply effort to begin pilot project.

J.Ward: Should set a "fund" adjustable and based on needs of maintenance.

B.Roberds: Critiques Neely & Rice paper; "Estimating Risk of Debris Slides After Timber Harvest in Northwest California".

N.Norrish: Discusses Golder Rock Fall Mitigation Project

K.Sullivan: Inventory? Golder should not assume that a computer storage system is not acceptable.

B.Burk: System must be reasonable.

K.Sullivan: Must be able to show good environmental performance; less frequency of failure. System will need to be verifiable (gives greater confidence in system). Should also be able to collect knowledge into system. Kate could not get a good agreement among the engineers to I.D. the problem [continuing stability] but several points were mentioned including; budget, organization, knowledge and process. To get implemented system must be "handy" for road managers. LOSS TO ENVIRONMENT is the highest priority of TFW & SHAMW.

B.Roberds: Asked if we are mainly looking at two user types; Generalists & Specialists.

K.Sullivan: Specialist = Tom, Matt or Jim Ward. Generalist = not entry level but maybe a Forester or [logging systems] engineer.

D.Wyllie: If propose to do an inventory [of stability] then must be done right the first time.

M.Spencer: May need to be able to alert one [kind] of specialist to call in another specialist [with the proper skills].

B.Burk: [He would define] generalist uses existing information [to make decisions] but specialists to extrapolate using current information.

B.Roberds: Perhaps generalists should be trained to I.D. certain criteria to find proper fix.

K.Sullivan: Believes that we can combine two levels to fine tune stability problems.

B.Roberds: Summarizes selected types of existing assessments;

	OLD ROAD	NEW ROAD	P(f)	CONSEQ	PRIORITY RATINGS	LEVELS	USER TYPE
CP-RAIL	YES	NO	YES	YES	YES	1	SPECIALISTS
WSDOT	YES	NO	YES	YES	YES	1	BOTH
USFS/MAP	NO?	YES	YES	SEPARATE	SEPARATE	3	SPECIALISTS
NEELY&RICE	NO	YES	YES	NO	NO	1	GENERALISTS
ROCK FALL	YES	NO	YES	YES	YES	1	SPECIALISTS
ROAD PAVE	YES	NO	YES	YES	YES	1	GENERALISTS
SHAMW GOALS	YES	YES	YES	ENVIRON	YES	2	BOTH

GROUP BREAKS FOR LUNCH UNTIL 1300

N.Norrish: Presents "straw-person" questionnaire. Planning to have W.Adams conduct interviews on a reduced scale from original proposal. Would like to add several SHAMW meetings to scope. Report Phase I on how to proceed.

Group responses to questionnaire: A-1;various data is used. A-2;mostly reactive and some proactive in adjacent areas. A-4 "mainline or secondary" is used in Weyerhaeuser. Abandoned;non-road but still get stability problems on the reclaimed land. Orphaned;roads not used since 1980 for forest practices.

B.Burk: Presents Factors Influencing Stability. Parameters include strength, geometry, pore pressure and unit weight.

	STRENGTH	DENSITY	PORE WATER	GEOMETRY
SPECIALIST	USCS	REL DENSITY	DIST. TO SPRINGS	SLOPE HT.
			PRECIP/SNOW	SLOPE ANG
			VEG TYPES	EROSION
GENERALIST	MATERIAL TYPE	TEXTURE	TOPOG	GEOMORPH
	ORGANICS		SURFACE CONDITIONS	
	FILL			

Group responds: USCS not used, mainly SCS/DNR but there is a correlation. Training needed to use USCS. Won't get soil descriptions from specialists.

N.Norrish: Need to look at rock, natural slopes and embankments?

D.Beedle: Are these categories things that we can expect specialist to plug into a slope stability model? [Has his doubts that specialist will be able to handle this data collection].

B.Burk: Must have some kind of interactive system.

J.Hurt: Keep in mind [the differences between] existing and new road problems. Questionnaire won't work if what we want is an inventory.

N.Norrish: Explains purpose of questionnaire. Asks if percentage of problems are in embankments or cutslopes.

Group: No consensus. Critical resource damage is a priority.

M.Spencer: [quote of the month] "There's a lot of gravity out there." Most managers have no concept of the causes of stability problems.

J.Ward/J.Hurst: Need to get organized method to attack problems.

GROUP BREAKS

D.Beedle: Do we suggest that SHAMW inventory everything to fix an area? Tribal land may not want to do work if not "fixing" something.

N.Norrish: Not necessarily recommend an inventory of Forested Lands BUT do need to have a "key" such as a drainage basin.

B.Roberds: Discusses continuous measure of P(f) which depends on if want "truth." Must increase quantity and quality of info to get increase in truth, so if have low probability of failure then don't need much reliability. Can note such things as; increase in slope angle produces an increase in probability of failure.

B.Roberds: Discusses Consequences.

- COSTS;clean-up,remediation,loss of service (access) & product
- SAFETY;transportation,housing proximity.
- ENVIRONMENTAL
- LIABILITY
- WATER QUALITY
- CREDIBILITY (AESTHETICS) /POLITICAL

N.Norrish: If were to rank?

Group: 1a) Environmental/Liability 1b) Safety 2) Credibility (what really becomes the priority)

N.Norrish: Surface water runoff failures:not part of our scope of project to give a surface water design. We may want to quantify stability problems in frequency per mile or tons per mile.

T.Koler: 2 levels: 1) with-in road prism/unless there's an increase in sediment to the drainage 2)number of events per mile. Geotech engineering: 10-50 yd3 inside the road prism and 200-1000 yd3 outside road prism.

M.Spencer: Cost/yd3 climbs at some rate.

N.Norrish: What if there is an environmental impact? If there is wrong doing then it's a legal matter.

M.Brunengo: Logging practices are assumed to be poor in some areas (Hoh river). Then logging stopped until prove that the contractor can prove that they have a better method.

M.Spencer: Would like to add to C-3 what is average annual maintenance costs.

D.Wyllie: As a decrease in maintenance then can expect an increase in costs to repair. In questionnaire: Is cost/yd3 independent?

B.Roberds: Discusses Consequences of failure;

- Clean-up costs:Waste/borrow proximity, material type, design materials, resources (equipment type), weather/season.
- Loss of Service:Traffic/type & alternative routes.
- Loss of Product:Size of failure, loss of resource (value of what is there) & (loss of access for fire protection), service area, Timber and non-timber resources.
- Safety:Road Traffic/recreation, dwellings, utilities.
- Environmental:Proximity to streams, wildlife habitat, fish species (ranked), botanical species, type of material, existing stream quality, stream category, city/fisheries.
- Political:Location (i.e. Deschutes River by Capital), perception (proximity or visibility to VIP or Individuals).

N.Norrish: Who are we to interview?

M.Spencer: Annual Engineering Meeting May 22nd & 23rd good time to talk to some individuals. [See phone numbers].

M.Raines/J.Ward: Contractors.

T.Koler: References; Williamson (URCS), Reilly (GRC/GRI), Neal (Current Practice in AEG), LISA manual, Precursor to WEPP.

M.Brunengo: Must visit his office.

N.Norrish: Answers to D.Beedle's questions; our interview questions will be different from those on the current questionnaire. We will have fewer individuals in interviews. Would like to meet again in one month. M.Spencer will get back to N.Norrish about DNR meeting.

D.Beedle: Keep in mind watershed and fisheries management.

APPENDIX B

QUESTIONNAIRE FOR DEVELOPING THE PRELIMINARY DATA SHEET

DRAFT

MEMORANDUM

TO: FILE, N.Norrish, B.Burk, B.Roberds June 28, 1991

FR: Wayne Adams

RE: INTERVIEW QUESTIONS (REVISED FROM DRAFT QUESTIONNAIRE 5/6/91) (913-1121)

A-1. What sources of information, such as maps, do you use to locate and deal with slope stability issues?

A-2. In dealing with slope failures are you reactive, proactive or both?

A-3. Do you use geotechnical analyses and designs, such as retaining walls or horizontal drains, in dealing with slope failures?

A-4. Do you use the terminology "Abandoned, Orphaned, Inactive and Active?"

B-1. In viewing the following list what are the most important in terms of failures within the road prism?

- unfavorable road location
- maintenance practices
- construction practices
- unfavorable geologic/soil conditions
- unfavorable/steep terrain
- unfavorable weather conditions
- unfavorable control of surface drainage
- design of structures (wood culverts, berms etc.)
- under-sized culverts
- debris in channel

B-2. Where do most of your slope failures occur? In cut or fill?

B-3a. Most of your slope failures (on ALL slopes) are in which material, soil or rock?

B-3b. These failures are mostly which, shallow (< 5 feet deep) or deep (>5 feet deep)?

B-4. DELETED

B-5. What volume range are most of your failures? Can assume "failure" to exclude slope ravel and creep features that would be handled under routine maintenance. Can also consider failures less than 50 yd^3 to be part of routine maintenance.

B-6. What age of roads are associated with failures? (by percentage)

B-7. What portions of the year do you get most of the failures?

B-8. DELETED

C-1. The most significant damage as a result of failure is which of the following?
- Sedimentation to streams
- Interrupted road service
- Traffic damage
- Cleanup costs
- Resource loss
- Human health & safety

C-2. In your experience, what failure volume size range is most prevalent? (by percent)

C-3a. What is the average annual cost due to slope failures on your land?

C-3b. How many miles of road (active & inactive) do you have on your property?

C-3c. What is the average maintenance costs for your roads?

C-4. What is the typical cost range for failures in your area? (by percent)

C-5. Which of the following do you use in repair of slope failures?
- Road cleanup during maintenance
- History of site problems to determine cause
- Geotechnical analysis of failures and design

D-1. Slope failures with-in the road prism could be reduced by which of the following?
- Improved road design
- Improved geotechnical design
- Improved adherence to construction procedures
- More maintenance funds
- Improved maintenance fund prioritization

D-2. How could you best benefit from specialists expertise?
- Training programs
- Improved access to geotechnical specialists
- Geotechnical manual
- Hazard maps or GIS system

W-1. How do you currently see the interaction between maintenance and engineering?

W-2. How do you currently identify stability problems.

W-3. Is hazard mapping feasible/practical?

W-4. Do you have computer capabilities?

W-5. How do you prioritize maintenance?

DRAFT

W-6. On what scale could you implement an inventory?

W-7. Do you track the slope failure/remediation history?

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APPENDIX C

BIBLIOGRAPHY

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